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MODERN ENGINES
AND
POWER GENERATORS

Frontispiece.] PETROL RAILWAY LOCOMOTIVE.

MODERN ENGINES

AND

POWER GENERATORS

A PRACTICAL WORK ON PRIME MOVERS AND THE TRANSMISSION OF POWER STEAM, ELECTRIC, WATER, AND HOT AIR

BY

RANKIN KENNEDY, C.E.

AUTHOR OF

"ELECTRICAL INSTALLATIONS" "ELECTRICAL DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS" "PHOTOGRAPHIC AND OPTICAL ELECTRIC LAMPS" AND NUMEROUS SCIENTIFIC ARTICLES AND PAPERS ON MECHANICAL AND ELECTRICAL ENGINEERING

WITH MANY HUNDRED ILLUSTRATIONS

VOL. III.

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PREFACE TO VOLUME III

THIS Volume is descriptive of prime movers on road vehicles—steam, oil, and petrol, with some further reference to the coming prime mover, the hot air or gas turbine.

The chief developments in prime movers for road vehicles and for small boats have been in the direction of improved internal combustion reciprocating engines, mostly of that class employing petrol fuel, and not of great powers.

The petrol-electric system has been adopted on one railway in a tentative way, and has much in its favour. It is a system worthy of more attention for road vehicles, as offering a satisfactory substitute for the complications introduced by mechanical gearing. For speed control, reversing and differential gear, mechanical devices must be inefficient, noisy, and in course of time develop slackness. The turbine has not come forward in road or rail traction, the principal drawback being the inefficiency of all turbines working non-condensing; a very high vacuum being required for any approach to satisfactory efficiency.

The application of internal combustion engines to small boats, mostly for sporting and pleasure purposes, has grown to some extent; but no serious attempts to solve the many problems arising in the question of applying internal combustion engines to marine propulsion have been made. It is evident that small engines using petrol or oil as fuel are out of the question for commercial purposes, and that coal of cheap quality must be used as the fuel in large vessels. This points to gas engines working with producer gas. For heavy road traction probably the same system can be applied. Coal, however, in a road vehicle does not constitute a large item in the expenses; as may be seen on page 182, it amounts to about 20 per cent. of the total.

The petrol and oil engines on road vehicles are rapidly nearing finality in design of reciprocating types. There is not much room for further developments in autocar piston and cylinder prime movers.

Some few small improvements in engines are referred to, especially that in the direction of constructing a valveless gas engine for working with producer or furnace gases.

This Volume concludes the descriptions and treatment of internal combustion engines for traction, stationary and portable purposes.

RANKIN KENNEDY.

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MODERN ENGINES AND POWER GENERATORS

CHAPTER I

GAS AND OIL ENGINES

BEFORE taking up the special subject of this volume, a few gas and oil engines require some attention, details of which have just become available for description. A great deal of valuable knowledge has been added to the subject of turbines by the improvements now made in wheel construction for high peripheral velocities, and the gas turbine has made further progress.

THE CAMPBELL GAS AND OIL ENGINES

The 16 brake horse-power gas engine with magneto ignition is shown in the page illustration, Fig. 2. In this design the cylinder does not overhang the end of the engine bed so much as is the universal fashion. The cylinder head overhangs of necessity to accommodate the valves and their levers. The construction otherwise does not differ much from the usual with gas engines. The side shaft works the valves, the ignition and lubrication, and is itself driven by skew gear. The leading features are excellent mechanical design and construction. One heavy fly-wheel maintains fairly even speed and steadiness for electric lighting, which is a sure test of steady working.

The oil engine is shown in Fig. 1, showing the self-starting compressed air reservoir. There are only two valves inlet for gas and oil, and exhaust valves. The oil is carried in a cast-iron drum on the top of the cylinder. The engine is constructed to work with oils having a close flash point test of 70° to 110° Fahr., or an open flash test point of 100° to 140°, weighing about $7\frac{3}{4}$ to $8\frac{1}{4}$ lbs. per gallon.

The inlet valve is shown in Fig. 3. It will be gathered from this Figure that the air enters from 3 and the oil by passage 4 and annular space 5 through holes in the valve seat 2. By this means the air and oil are sprayed into the vaporiser. They are drawn in by suction, and the spring of the valve regulated by the nuts 7 and 8.

The exhaust valve, the only one operated mechanically by the engine, is shown in Fig. 4 in section on the cylinder end. The governing is on the hit-and-miss principle.

The self-starting valve and lever for starting under compressed air is shown in section in Fig. 5. Pipe B leads to the engine cylinder, A to the compressed air reservoir.

It will be readily seen that if the piston is in position to start,—a position it can be

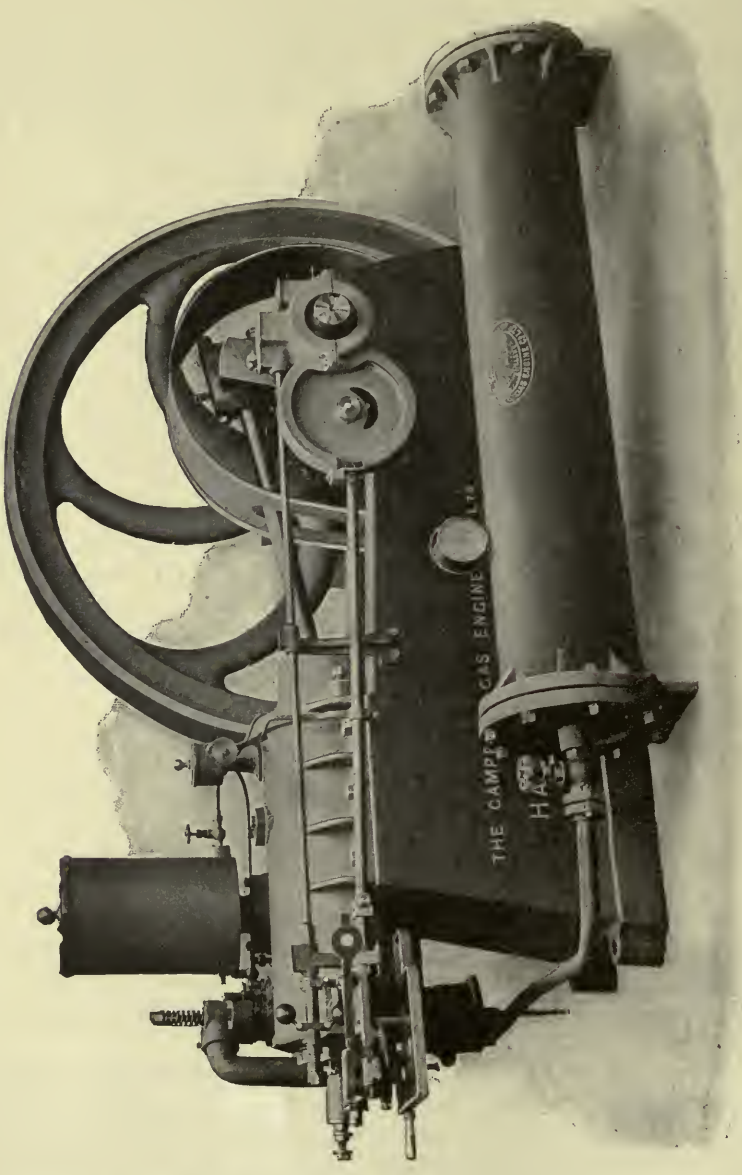


Fig. 1.—Campbell Oil Engine and Air Reservoir.

placed in by barring,—and the lever 4 pressed down, the valve will be opened, a blast of air admitted behind the piston to drive it forward; a puff or two more will get up speed, when the oil may be turned on, and the engine started to work itself.

Fig. 7 is a line drawing plan, and Fig. 6 a sectional plan of the same engine. The vaporiser is heated by an oil lamp. It is shown in the sectional plan. The air pipe enters at M and the oil at C by passage Y to the combustion chamber.

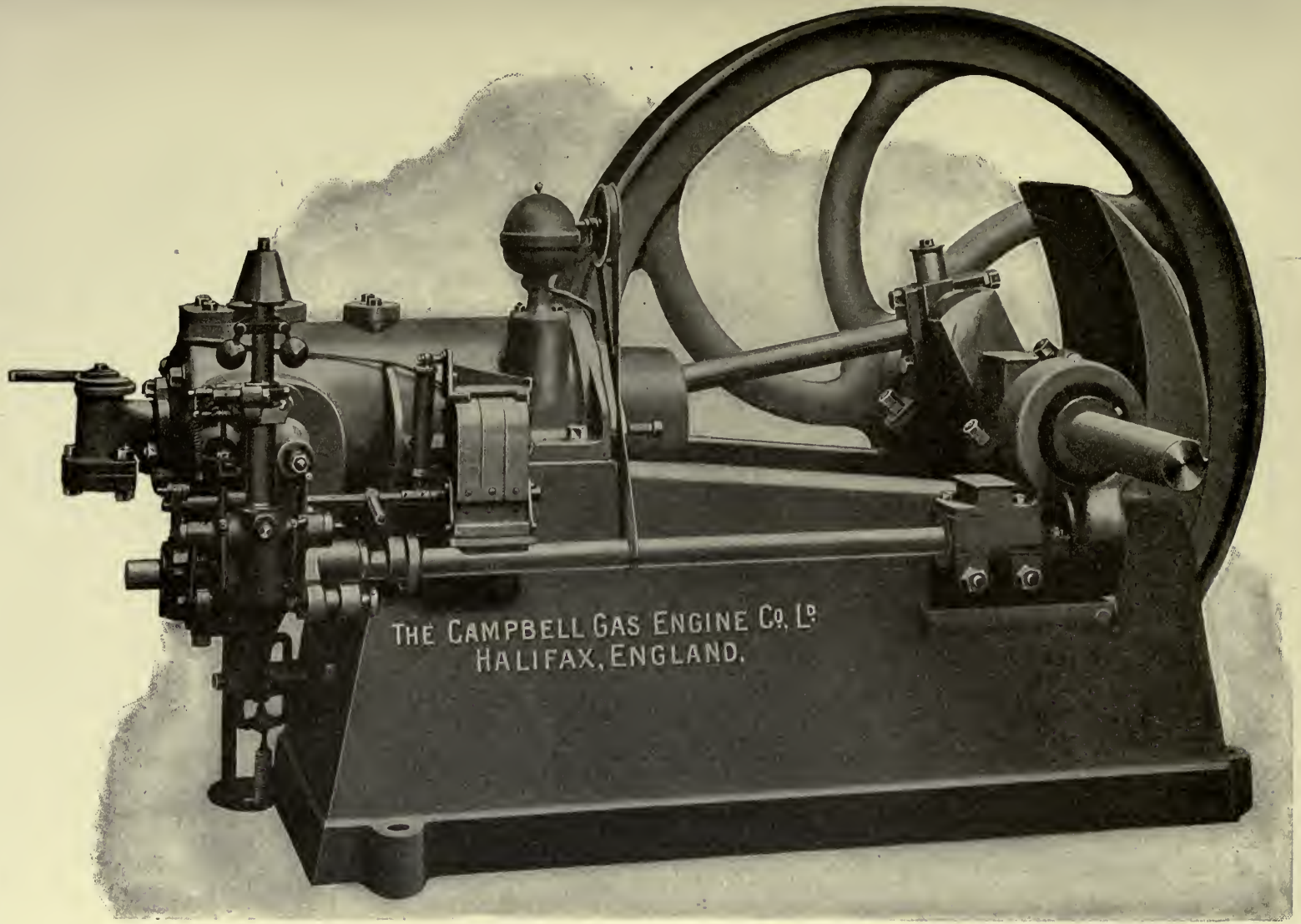


FIG. 2.—Gas Engine Magneto-Electric Igniter.

Fig. 7 shows the governor and valve gearing, of which the following are the various parts:—

1. Governor skew gear wheel.
2. Governor skew gear pinion.
3. Governor rod.
4. Governor spindle.
5. Governor sleeve.
6, 6. Governor balls.
7. Governor spring.
8. Governor adjusting nuts.
9. Governor lever.
10. Governor balance weight.
11. Governor drop rod or drop piece.
12. Governor steel piece or steel bit.
13. Governor bracket.
14. Exhaust valve lever.
15. Exhaust valve lever fulcrum pin.
16. Exhaust valve lever set screw.
17. Exhaust valve lever steel piece or steel bit.
18. Exhaust valve lever spring.
19. Spur pinion.
20. Spur wheel.
21. Eccentric.
22. Eccentric straps.
23. Eccentric rod.
24. Pusher piece.
25. Half-moon pieces.

The spur pinion (19), which is keyed to the crank shaft, gears with the spur wheel (20) as described below. The eccentric (21) is cast in one piece with the spur wheel (20), and through the eccentric rod (23) drives the pusher piece (24). The pusher piece comes into contact with the set screw (16) on the exhaust valve lever (14), and through this lever opens the exhaust valve at the right moment, and allows it to close again when the burnt gases have escaped.

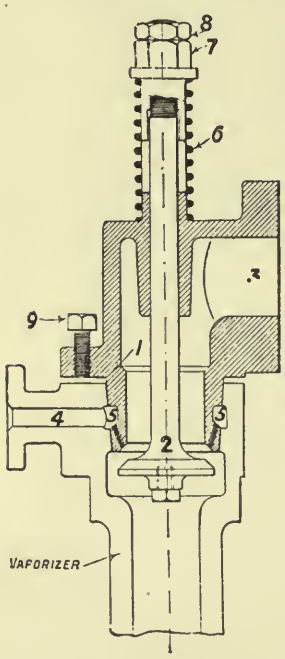


Fig. 3.—Inlet Valve.

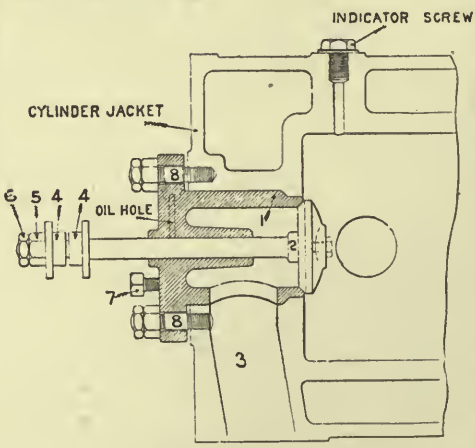


Fig. 4.—Exhaust Valve.

The skew gear wheel (1), which is keyed to the crank shaft, gears with the skew pinion (2), and through the governor rod (3) and spindle (4) causes the sleeve (5) and balls (6, 6) to revolve.

The balls have inwardly projecting arms, which fit easily in a slot in the governor spindle, in which slot they are free to move. It is by these arms that the balls are driven.

The arms of the governor balls work on steel pins in the governor sleeve. The sleeve is a sliding fit on the governor spindle, on which it can move freely to and fro, controlled by the spring (7). The spring can be compressed more or less by the adjusting nuts (8), and the speed of the engine increased or diminished by this means.

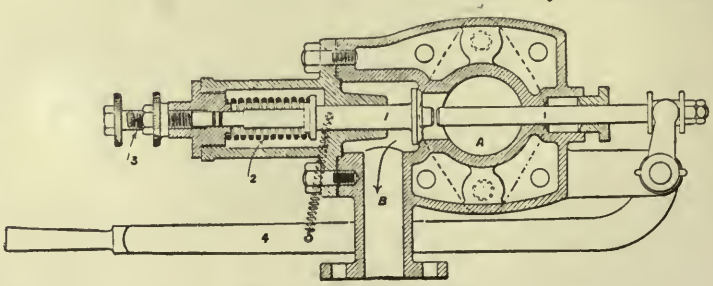


Fig. 5.—Starter Lever.

The half-moon pieces (25) attached to the short end of the governor lever (9) fit the groove in the governor sleeve. The drop rod (11) is hinged by a steel pin to the long end of the governor lever, and carries at its lower end the steel piece (12), which is secured in position by a nut.

As long as the load on the engine requires it, charges of oil and air are drawn into the cylinder through the vaporiser,

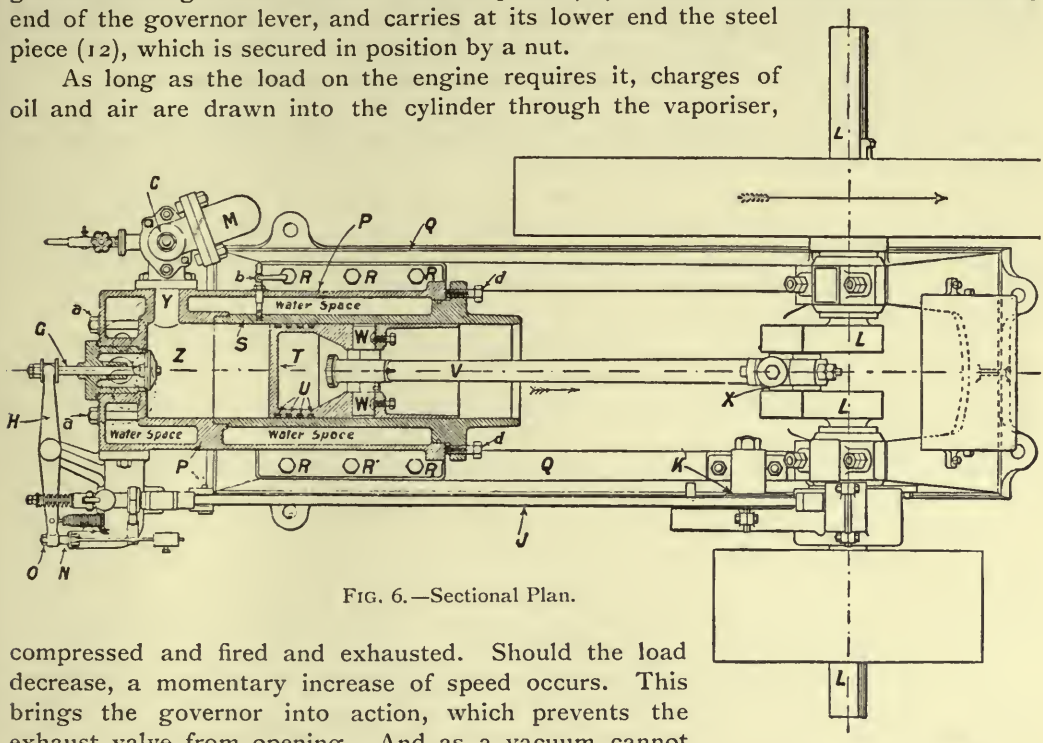


Fig. 6.—Sectional Plan.

compressed and fired and exhausted. Should the load decrease, a momentary increase of speed occurs. This brings the governor into action, which prevents the exhaust valve from opening. And as a vacuum cannot be formed with an open exhaust valve, no oil is drawn in through the inlet valve, and so the speed of the engine is checked.

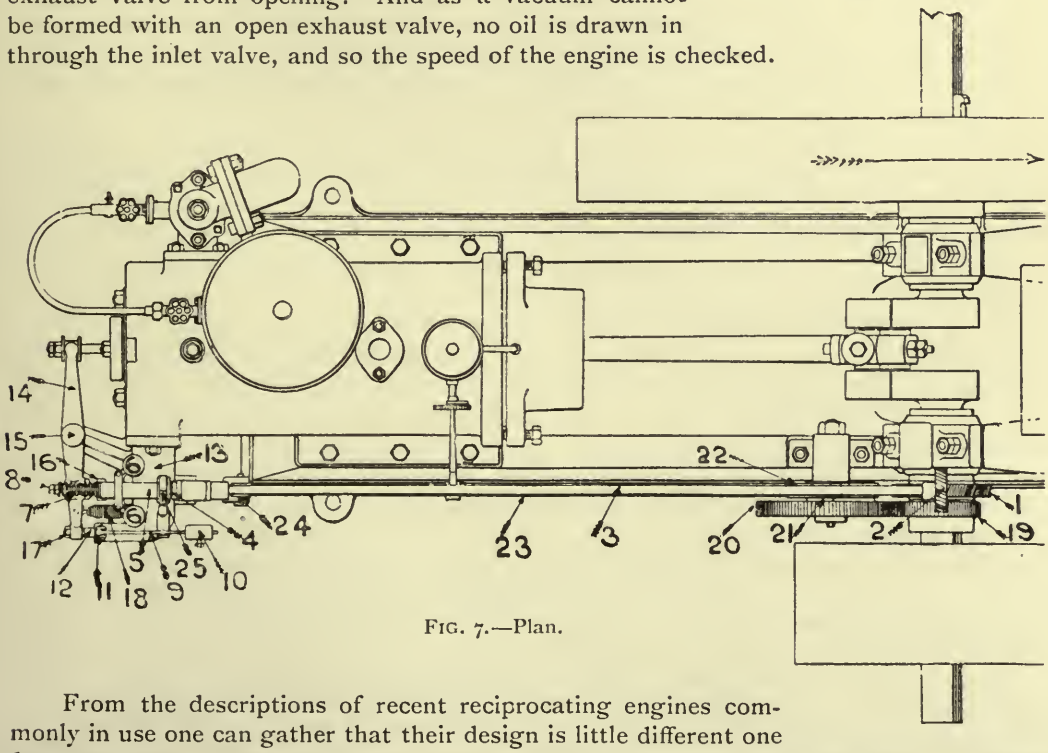


Fig. 7.—Plan.

From the descriptions of recent reciprocating engines commonly in use one can gather that their design is little different one from the other. The 4-stroke oil and gas engine have become standardised in pattern

and mode of action. Hot tube or magneto ignition is common, and the self-ignition by compression and hot vaporiser once the engine is started—doing away with all lights and lamps and magnetos—is rapidly becoming the only system, especially with oil engines. From that to the Diesel engine is a short step. The igniter must go with all its troubles.

In all likelihood we shall always have the following standard types of internal combustion engines :—

1st. The common 4-stroke gas engine, working on town's gas,—tube or electric ignition.

2nd. The same engine, working with a suction gas producer,—tube or electric ignition.

3rd. The common 4-stroke oil engine, with high flash 75° to 160° oil,—with self-ignition by compression and hot vaporiser, after first heating by lamp.

4th. The Diesel engine type.

Then special engines at present not settled down to any standard. These are: —The furnace gas engines; producer gas engines for marine propulsion; 2-stroke engines and double acting 2-stroke engines; reversible engines for marine purposes; gas producers for marine purposes; gas turbines.

Recently the furnace gas engine has made rapid progress, and there is little doubt that it will be adopted in every blast furnace iron works.

Producer gas engines for land purposes are now receiving more attention, and are generally appreciated as a cheap source of power; so much so that their advent has much damaged the prospects of the propositions to supply cheap electrical energy from large steam power centres, as it is a fact that no steam power, however large, can compete in price with gas producer and gas engine power.

The gas producer and gas engine are surely destined to oust the steam plant as prime movers.

The 4-stroke engine, at present so common, is not the final form of engine. An engine will be evolved on the 2-stroke principle, single and double acting for large powers, and especially for marine work, and with effective controlling apparatus for reversing and modifying the speeds. This introduction of large powers on shipboard, of course, leads to improvements in producers to meet the altered conditions.

The gas turbine is the form of internal combustion engine, at present in its most primitive form. But the difficulties are not so much engineering or technical in nature as they are financial. The working out of a commercial gas turbine, even although beginning with the knowledge of all that has already been done, and with a sound education of the physical and mechanical sciences connected with heat engines, will be costly in time and money, but it will be accomplished.

Gas engineering being concerned with the "prime mover" question, is of far more importance than electrical engineering, which at best is only "a transmitter of power business." The future of gas engineering is brilliant with promise. Not only is it at present a large industry, but what is of more importance, it is a *growing* industry in every direction at home and abroad.

The past twenty years have seen vast developments in power transmission by electricity, the power being generally derived from fuel through steam; but the power of the future is more than likely to be from fuel through gas. Gas power is a distinct advance upon steam power in many respects. First, it is cheaper by 30 per cent. if gas producers are used. Secondly, it relieves us of the trouble and expenses attendant upon high-pressure boilers, and no smoke is produced, no large chimney required. In this power question we are again confronted by the inertia of those in whose hands the adoption of one or other kind of power has been placed long after it has been clearly demonstrated that steam is inferior to gas power. The "leading engineers of high standing," to quote one of themselves, are still to be found advocating the steam régime. But it is significant that gradually all over the country enterprising engineering

manufacturers are equipping their own works with gas producer plants and engines, and a few extracts from a paper kindly sent by Mr. Bellamy, as read by him before the Manchester Society of Engineers, will show what can be done in driving a factory. The factory referred to is that of Messrs. J. E. H. Andrew, Stockport. His claims are as follow, and are not in any way exaggerated in favour of gas :—

Dealing first with the power for driving the works, there is in an old shop 45 indicated horse-power, and in the new shop 24 indicated horse-power, or a total of 69 indicated horse-power. The gas consumption worked out at the rate of 67 cubic feet per indicated horse-power per hour. The costs were taken for an ordinary working week of 53 hours, with an allowance of one hour for the time the engines are running before and after the shop hours. $69 \times 67 \times 54$ equals a total consumption of 249,642 cubic feet of fuel gas, say, 250,000 cubic feet. Reckoning 14 lbs. of fuel per 100 cubic feet, then the coal used equals 3500 lbs., which at 25s. per ton amounts to £1, 19s.

Tabulating the total cost for one week equals :—

Fuel	£1 19 0
Labour (one man at 25s. per week)	1 5 0
Oil and waste for engines	0 4 0
Interest, depreciation, and repairs at 10 per cent. on capital outlay of £900	1 16 0
Total	£5 4 0

which is at the rate of a little under 2s. per hour. Reducing the cost to a single horse-power per hour, a total of 3726 horse-power-hours, at a cost of £5, 4s., is at the rate of $\frac{1}{8}$ of a penny per indicated horse-power per hour, which covers all charges.

Gas Consumption.—As the engines are worked with fuel gas, the gas consumption was obtained in this way:—The gasholder was filled with gas, and all connections shut off between the producer and the gasometer. The engine was then indicated, and the number of explosions registered by the counter for each foot of fall of the gasholder. As the holder has a capacity of about 6000 cubic feet, the result can be considered as accurate.

Fuel Consumption.—This has been frequently tested, and it is found that, taking an average working week of 53 hours, the quantity of anthracite coal required to produce 1000 cubic feet of fuel gas is 14 lbs., which includes stand-by loss, and an allowance for generating the necessary steam for making the gas.

Cost of Labour.—The gas plant is fixed in close proximity to the steam boiler. This boiler is principally used for generating steam for the steam hammers, and for heating the factory when required. One man attends to the boiler and the gas plant, and it is found that the latter does not take up half his time. One of the labourers looks after the gas engines, but this does not occupy his attention more than two hours per day. It is therefore assumed the wages of one man would be 25s. per week to attend the gas plant and the two gas engines. This is an ample allowance, and from experience would be sufficient for double the power.

The cost of water has been neglected, as the quantity used is very small. The amount required for making the gas is less than 1000 gallons per week, and there is also a little loss from evaporation in the water which circulates through the cylinder jackets. This water is obtained from a well.

The cost of the fuel gas per 1000 cubic feet works out as follows :—

Fuel per week (3500 lbs. at 25s. per ton)	£1 19 0
Labour (half man's time at 25s. per week)	0 12 6
Water	0 0 0
Interest, depreciation, repairs at 10 per cent. on £400	0 16 0
Total	£3 7 6

As the total quantity of gas made is 250,000 cubic feet per week, the cost therefore works out to $3\frac{1}{4}$d. per 1000 cubic feet.

It is only fair to say that one man could work a plant of twice the capacity, and in so doing the cost of labour would be materially reduced. Again, an addition of £100 expenditure would double the output of gas, so that the item for interest, depreciation, and repairs would be materially decreased.

In order to make a comparison with a steam engine, take 3726 horse-power-hours for a total consumption of 3500 lbs. of fuel; this equals .939 of a lb. per indicated horse-power per hour, and includes all stand-by losses. It may be said that the cost of the fuel per ton is very much higher than ordinary steam coal; but allowing it to be three times as costly, it then comes out at the equivalent of $2\frac{3}{4}$ lbs. per indicated horse-power for 69 indicated horse-power, a result which will compare most favourably with the best steam engines of much greater power.

Outside the question of economy, there are many other advantages over steam, among which are the following:—

Start at a moment's notice.
No time lost in getting up steam.
Less stand-by loss.
Practically no smoke.
Less fuel to handle, and little or no ashes to remove.
Great economy in water.
No tall chimney to build and no flues to clean.

This now completes the descriptive treatment of stationary gas and oil engines, and the results of their working. The theoretical part of the subject, with considerations of practical importance thereon, will be entered into in the general discussion of heat engines and heat.

The animadversions made against the use of the motor car engines on boats or ships do not apply to motor cars. These slimly built enclosed engines are necessarily compactly and as lightly designed as possible, and the power developed per lb. of engine is marvellous, but their durability and reliability and cost of working are all against them for marine work, except in the case of enthusiastic motor car engine makers desirous of an outlet for the manufacturers. No engineer would ever consider an engine, however well designed, and made for a road vehicle, as suitable for a ship; might as well say a railway locomotive is suitable for steam ship propulsion. The introduction of unsuitable engines for marine propulsion at this stage will result only in failure and subsequent injury to what might soon become a profitable industry. One or two failures have more effect adversely than twenty successes favourably.

The gas engine working with producer gas deserves far more attention from power users than it at present receives. It is really the cheapest working prime mover known to the world. Advantage is not at present taken of this fact. The present generation of leading engineers have been reared and practised in the highest developments of the steam engine, and naturally cling to it. But the time is near when other engineers will take their place, whose knowledge and training are more recently acquired, and their environments different. The internal combustion engine and gas producer will not appeal to them in vain. In fact, they will be compelled to consider other prime movers than the steam engine, for the coal supplies of best qualities must rise in price and go on rising after a comparatively brief period. At the present moment the cost of coal is kept down by several economic causes, acting only with force, so long as the store of coal is practically unlimited. Every one interested in making money out of coal must make it a first principle that the more coal passed through the market in a given time, the more money is gained in that time. Coal is not harvested once a year like products of the land; it can be harvested as fast as power and energy can be applied. The con-

sequence is that the landlord who owns the coal field, and the colliery proprietor who gets out the coal for sale, make their chief endeavour to get out the greatest quantity in the shortest possible time. By doubling the output they can double their income. Hence our coal mines not only supply all the needs of this country, but also supply foreigners with a huge export of coal, and this rapid output it is which keeps down coal prices to present figures.

But this increase of output cannot go on for ever, the time approaches when the coal beds will fail to supply the vast demand. Seams at present too thin or too deep or otherwise too costly to work will have to be opened up ; the best coal will go up in price first, and once the upward movement begins it will go on until the coal is exhausted.

For these reasons, not only must the next generation of engineers, as the present have done, study how to get the most power out of the least amount of fuel, but they will also be compelled to adopt prime movers capable of working with the *poorest qualities of coal* with high economy.

In this respect we need not look to the steam engine, but take up with the gas engine, in which the heat is better utilised, and that heat obtained from a smaller quantity of cheaper coal than can be used in steam power.

Proposals have been made to restrict the output of good coal by legislation, also to tax its export, others again write enthusiastically about science discovering means to do without coal altogether ; while all the time the solution of the problem, so far as it goes at this date, lies at their feet unrecognised, in the gas producer and gas engine, in which they can obtain one horse-power-hour for the expenditure of half the weight of coal required by steam, and that coal, moreover, of a very inferior quality.

CHAPTER II

LOCOMOTION

INTRODUCTORY

In this volume it is proposed to describe the mechanical means whereby prime movers are applied to moving vehicles on roads and railways. Almost as soon as the steam engine became a successful prime mover inventors began to plan its application to locomotion ; and Murdoch, the gifted assistant of James Watt, built a model engine on wheels which ran on the road.

The history of the steam locomotive and the railway systems does not belong to a work like this. Motor cars and traction engines come under the generic term Locomotive, inasmuch as they are machines which can of themselves move from place to place by a prime mover forming a part of themselves. There are few electric locomotives, and these only of small power run by electric accumulators ; there are no commercially successful electric prime movers. The "electric" tramways and railways are essentially steam tramways and steam railways in which the steam power is transmitted electrically to the moving car or train, the electric vehicles being powerless to move of themselves from place to place.

Road locomotion by so called motor cars has assumed an important magnitude of recent years, but not in a direction of much utility, the bulk of the trade in these light locomotives being for sporting and pleasure purposes. However, of late, omnibuses and waggons have to some extent been used for trade purposes.

In our climate people will never go back to the state of affairs existing in pre-railway times, the masses and the classes alike will always take railways when travelling for business or on long journeys. Road travelling is only for amusement, or to places where no railway connection exists. It has been said with truth that there are many places with no railway connection, but never a place with no road to it. The road car has also a considerable use in running from place to place in cities and large towns.

The machinery of road vehicles and their prime movers have vastly improved of late, due to the fashionable vogue of the motor car, and at present the whole essentials for reasonably certain and comfortable locomotion have been fairly successful, while still leaving room for improvement in the engineering designs. The prime movers and their gear are admirably adapted for road locomotion in many respects, and a fair volume of business is done in motor cars. We shall consider several forms of prime movers for locomotion, and follow up with the older types—Traction Engines, Motor Cars, Petrol, Oil, Electric, and Steam for road vehicles.

Vehicles built for trade purposes are not so common ; the prices are too high at present, to begin with, and the cost of repairs and amount of annual depreciation are important factors in the question of adopting prime movers instead of horses. For sporting and pleasure purposes these considerations have less weight. Most of the high-speed

motor cars on the roads to-day will in all likelihood reach the scrap heap in five years. This short life would deter anyone from substituting the light mechanical for the horse vehicle for commercial purposes. Therefore we find two distinct classes of prime movers—the light weight fast speed machines for motor cars, and heavy durable strongly designed engines for heavy road traffic and for boats for practical work. But even although the attention of capable engineers has been expended largely on trade vehicles, the business in them is by far smaller than that in the light motor cars. This is surprising, for manufacturers in large inland towns have for long been handicapped by the heavy rates for the railway carriage of goods. It was thought that while travellers would not return to the roads again, that goods might be carried cheaper by road than by rail if good road vehicles mechanically driven were provided. This has not as yet been realised, but it no doubt will come about in time. The author knows of a case in which an American firm found it a considerable saving in carriage of heavy machinery to ship it from New York, U.S. America, to Glasgow, rather than send it by rail from a stock in London to Glasgow. And further than this, the railways work the handling of goods in transferring them from vehicle to vehicle on as cheap a system as possible, which in the end simply means few men, and so the goods are knocked about without much care, resulting in damages, and demanding expensive packing; whereas goods sent by road can be cheaply packed and taken on at the sender's place, and so need not be touched until they reach the consignee. There is a great deal more to be said in favour of heavy road traction by modern engines that can be said in favour of passenger traffic on roads.

In this connection it is of great interest to note that the War Office organised a test of road tractors driven by oil engines in 1903. The conditions of the test were stringent, and were as follow:—

The tractor was not to exceed a gross weight of 13 tons when fully loaded with all its fuel and water, and with all stores necessary for its proper manipulation in the march, and must be independent of any extraneous machinery for the supply of its motive power. It was to be able to complete a run of 40 miles, hauling a gross load of 25 tons, and at a speed averaging 3, but not exceeding 5 miles an hour over average roads with gradients up to 1 in 18. It was also to be able to run up to 8 miles an hour on a level road, with 12½ tons load; to climb a hill 1 in 6 with the same load; and to go through 2 feet of water. It was to be fitted with winding gear, carrying 75 yards of flexible steel-wire rope, with a breaking strain of not less than 15 tons, and capable of working fore or aft, or within 90° either way. Other conditions applied to the motive power: in the case of steam engines, relating to the boiler, condenser, and liquid fuel; in the case of internal combustion engines, relating to the flash point of the oil used, which must not be less than 75° Fahr., and the starting gear, and absence of noise and shock. It will be gathered from these particulars of the conditions that the problems resolved itself into one for providing an engine of high power which, with every requisite for the generation of power, should come under the maximum weight demanded for military purposes. When it is remembered that the ordinary steam road traction engine requires a fresh stock of coal and water every 10 miles or so, it will be seen that the problem was one of great difficulty, and needing the highest engineering skill.

The competition was thrown open to engineers throughout the world, and it was rumoured that several firms—not only British, but American and German—contemplated entering the competition. Only one firm, however, persevered and faced the judges, Messrs. R. Hornsby & Sons Ltd.; and having gone through the trials satisfactorily, they have now been awarded the First Prize of £1000, together with £180 bonus, which represents, according to the conditions, that, instead of 40 miles, this tractor made a run of 58 miles with the store of fuel carried under the limit of weight, thus exceeding the demands by 45 per cent.

The trials took place over the well-known trial grounds near Aldershot, and included the rough roads and steep hills of that district, as well as the notorious Long Valley—a wilderness of soft sand, the nearest thing to the African veldt that England can produce. The engine travelled by road from Grantham to Aldershot—150 miles—and also home after the trials. The trials extended over 500 miles, and previous to this, over 200 miles had been done during the experiments in the neighbourhood of Grantham, in the uplands of Lincolnshire, so that over 1000 miles has been run by the tractor with practically no signs of wear. After the trials at Aldershot the engine was opened for inspection, and all bearings and wearing parts examined, and found in perfect condition.

HORNSBY OIL TRACTOR

The engines of Messrs. Hornsby's make for stationary purposes we have already described. On this traction road vehicle the engine has two cylinders, placed one above the other, the connecting rods being coupled up to the same crank pin, and as they work on the Otto 4-cycle principle, at alternate intervals, there is an explosion given for every revolution of the crank shaft. The common crank shaft makes 350 revolutions per

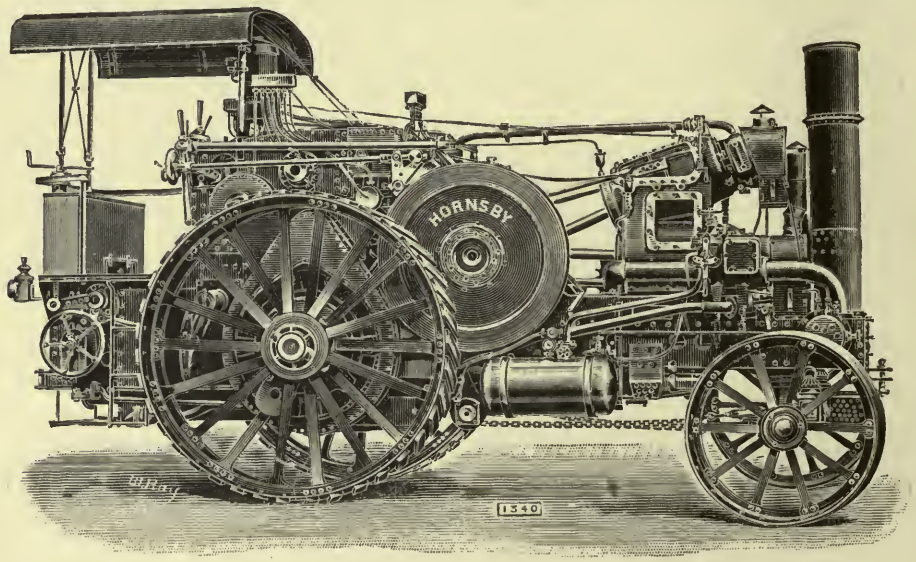


Fig. 8.—Oil Tractor.

minute. Three oil tanks are provided with a total capacity of over 100 gallons. The oil used is refined Russian oil, but adjustments are provided so that either refined American, Scotch Shale, Crude Russian, Astaki, Texas, Liquid Fuel, or Burmah oils can be used. In this respect the Hornsby-Ackroyd engine is unique, and has no rivals. The cylinders are water-jacketed, and the water is circulated by a rotary pump round them, and through a cooler placed under the footplate, the air being drawn over the tubes by a fan. An important factor in the problem was the consumption of fuel and water—a matter in which the Hornsby-Ackroyd oil engine is unrivalled. The consumption of oil fuel on good average roads in about 30 miles, with the maximum load, is about 350 lbs., and the consumption of water for cooling purposes, for the same distance and load, under one gallon.

A silencer for the exhaust is placed in the front of the frame, having a chimney at the top that acts as a second silencer, as well as to lead the exhaust to the atmosphere.

The gearing is arranged with four speeds—1½, 3, 5, and 8 miles per hour,—reversing and winding gear.

The lubrication of all the parts is one of the most interesting features of this engine. Every moving part and bearing has its own separate lubricator, and is supplied by a copper tube from central reservoirs.

The whole of the gearing and lubricating, and every movement necessary for the complete working of every function of the engine, is under the control of the driver on the footplate.

Fig. 8 represents this tractor complete. Here we have a self-contained locomotive for road working of goods traffic. Oil is at present the only fuel possible, but there is some prospect of using coal in this case as well as on board ship by a properly designed "producer" of gas. In this country oil can be procured and freely used, and there should therefore be a large number of traction oil engines employed in goods traffic at no distant date. The details of the traction engine and gearing are similar in nearly all makes, and will be considered in their place later on.

THE WOLSELEY OMNIBUS

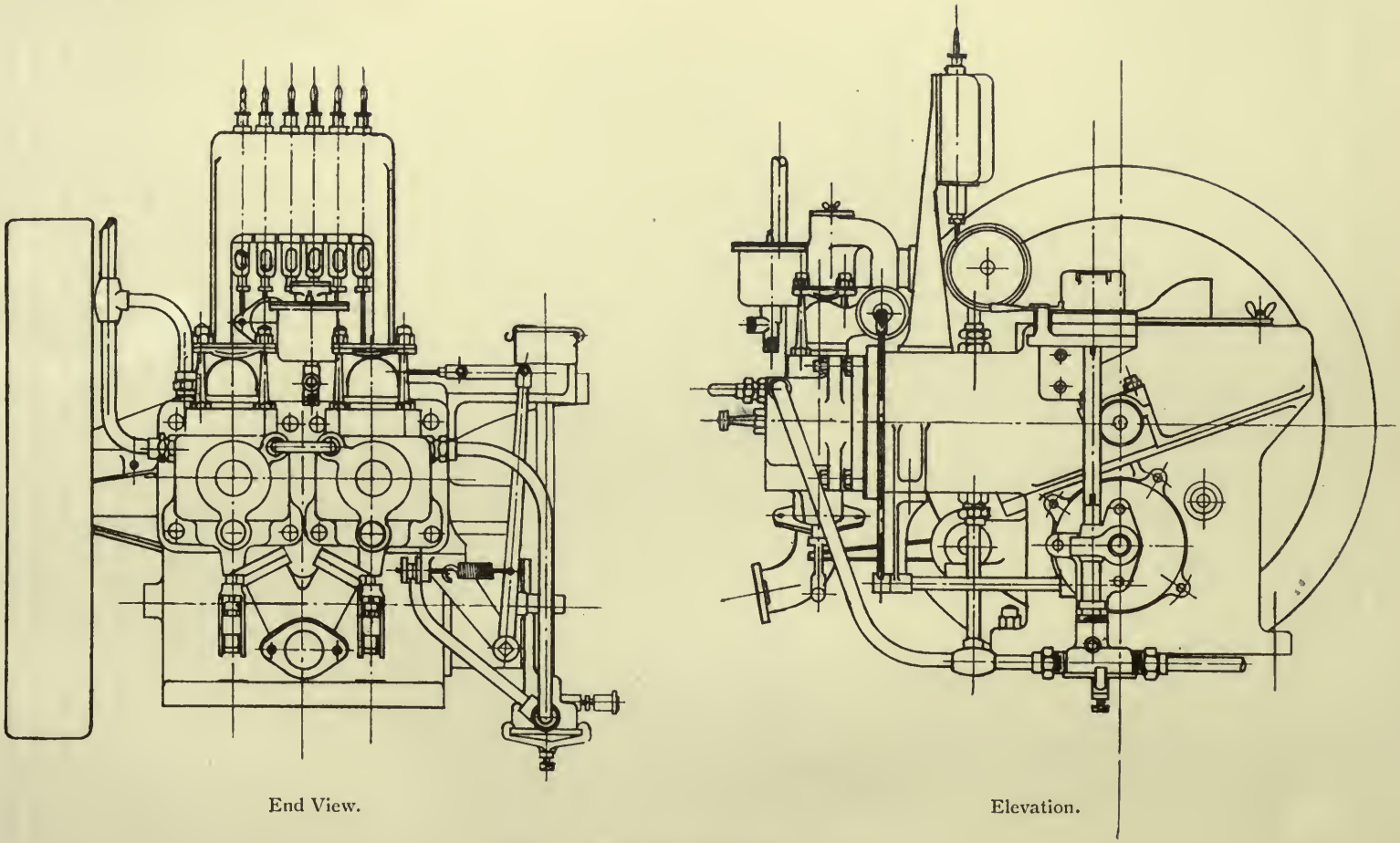
This is designed for public service and seated for twenty-two passengers. It will be necessary first to describe the prime movers in the Wolseley vehicles. It differs considerably in design from the common vertical inverted cylinder motor car engine.

The general arrangement of the 2-cylinder motor is clearly shown in Fig. 9. It will be seen that the engine is of the horizontal type and has two cylinders, both on one side of the crank shaft. The cylinder jackets are made in one piece with the upper half of the crank chamber; the lower half with pump, commutator, and exhaust lever fittings being really detachable.

There are two cylinders $4\frac{1}{2}$ inches diameter and 5 inches stroke, developing 12 brake horse-power at 750 revolutions. The cast-iron combustion chambers have a ground conical joint between them and the cylinder liners, these in turn being jointed to the crank chamber and water jacket casting in the same way, there being no joint to be made between water and combustion space. The fly-wheel is carried on an extension of the crank shaft, and has its internal periphery coned to receive the male member of a friction clutch. The crank shaft is extended beyond the fly-wheel, and can be modified within reasonable limits to suit requirements.

The cylinder and combustion chambers are cooled by water circulation maintained by a small rotary pump driven off the farther end of the pump shaft. All the valves are of the mushroom type. The inlet valves are automatic, and are placed on top of the combustion chamber with the positively actuated exhaust valves immediately beneath them. These latter are lifted against coil springs by kickers, the other ends of which are actuated by cams on the two-to-one shaft. This shaft is placed vertically beneath the crank shaft, and driven therefrom by spur gearing. An arrangement of auxiliary sliding cams on the same shaft comprises the half compression arrangement for starting purposes.

An extension of the two-to-one shaft carries the spiral gear for driving the pump shaft, and also the electric commutator. This is of the internal contact type encased in a dirt-proof aluminium box with a spring clip cover. The spring plunger travels round the insulated ring, making contact at intervals with one or other of the two metal insets. For the purpose of timing the ignition the whole casing containing the contact ring may be rocked about its axis. The spiral gear driven pump is of the rotary type, with two small spring plungers constantly pressed outwards against the internal periphery of the excentric pump wall. The carburetter is of the usual float feed spray type, and is connected through a branched induction pipe to the two inlet valve castings. There is one jet and float feed to the two cylinders. Between the carburetter and the induction valves there is interposed a throttle slide gear for regulating the supply of mixture. Automatic gravity feed lubrication is provided for, oil pipes being conducted to all important bearings from a sight-feed lubricator. Ignition is effected by electric



End View.

Elevation.

FIG. 9.—Wolseley 2-Cylinder Petrol Engine.

sparking plugs, the current being supplied by battery or accumulators and transformed into high tension by an induction coil. The weight of the complete engine with carburetter, pump, commutator, etc., is 320 lbs.

The standard 12 horse-power motor is supplied without a governor, but when desired one can be fitted on an extension of the pump shaft actuating an auxiliary throttle. Fig. 9 is an end view in line drawing, and a side view. Figs. 14 and 15 are two sections of the 7½ horse-power engine showing the details of construction, and are 3 inches to a foot scale. The general arrangement of the bus is clearly shown in Fig. 10. This bus is specially designed to meet the requirements of railway companies establishing "feeder" services in their outlying districts, and of all public service vehicle companies requiring an absolutely reliable omnibus, which has been specially designed for the work, and has embodied in it all the latest ideas suggested by the rather unsuccessful experiments of other manufacturers which have taken place during the past two or three years.

The employment of the horizontal standard engine enables radical departures to be made from the ordinary type of motor vehicle. It is no longer necessary to allocate a quarter of the space on the chassis to a bonnet containing the engine. The whole of the

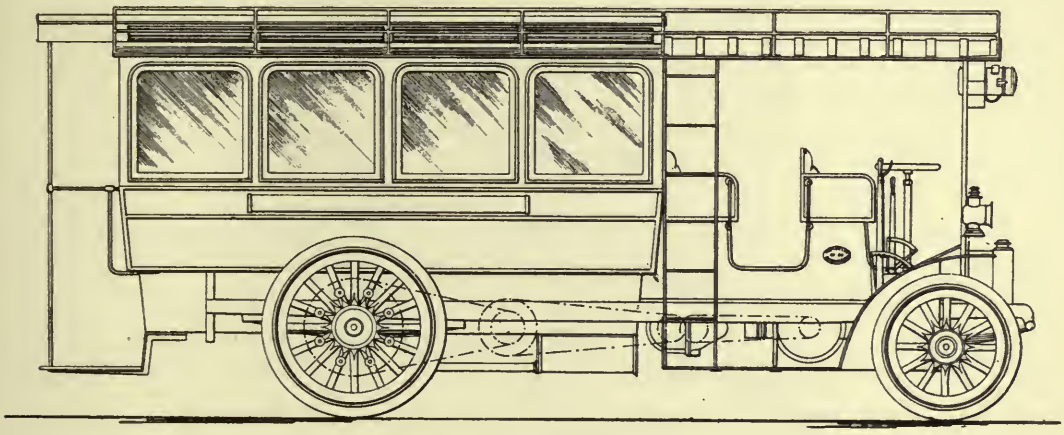


FIG. 10.—Petrol Omnibus.

engine, gear case, and mechanism is carried conveniently and compactly below the frame line. This renders the whole of the chassis available for seating accommodation.

The type of change-speed gear box is adopted with auxiliary side chain drive, and this allows a main bus body to be carried very low between the frame, with the concurring advantage that baggage on the top does not have to be carried so very high, and the vehicle will be easier riding and steadier on the road.

To meet the demands of a certain section of the public who prefer to ride outside, and in preference to the construction of a double-decked vehicle, two transverse seats are arranged in front. The driver's seat will hold, besides the driver, two passengers, the second bench holds four passengers. The bus body proper holds sixteen passengers, eight aside, with a step for conductor outside ; twenty-four persons in all.

Owing to the body being carried so low in the frame, the bus is built higher in the roof than usual, and is provided with large windows, the same to be removable in summer if necessary. This renders the interior exceptionally roomy, well lighted, and well ventilated. The body is fitted with a clerestory roof, and luggage rails and straps from end to end The clerestory, which is fitted with ventilating louvres, is extended towards the back as a shelter for the conductor, and the main roof is carried right over the front of the dashboard.

Great care has been taken with the design to ensure that all parts of the mechanism

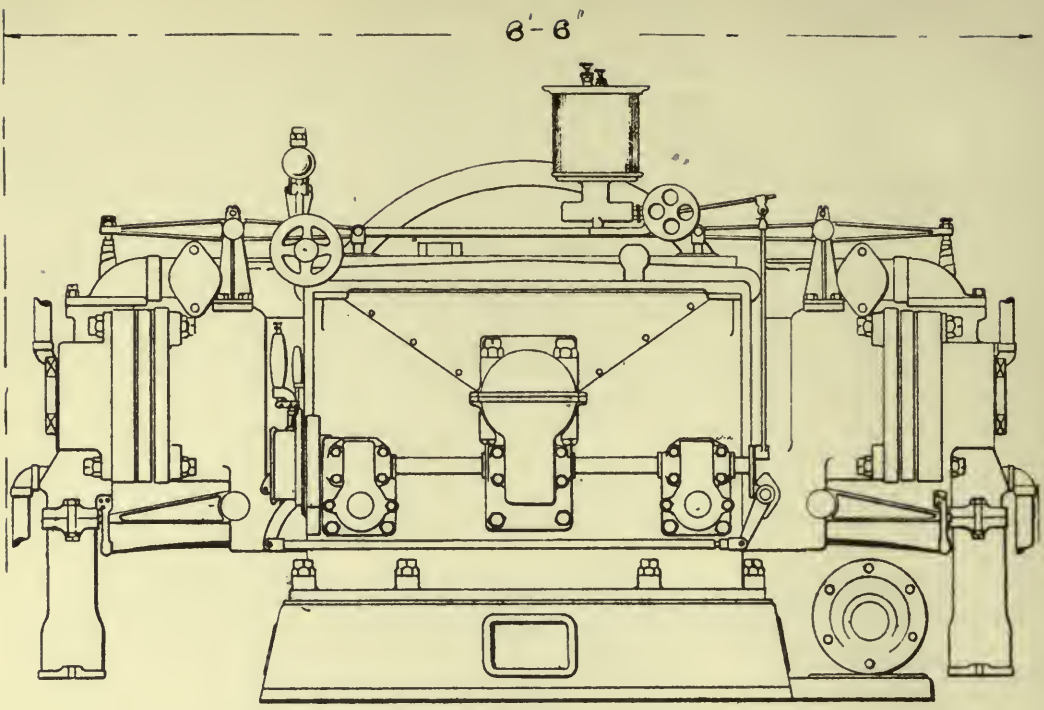


FIG. 11.—Elevation of Wolseley 4-Cylinder Engine.

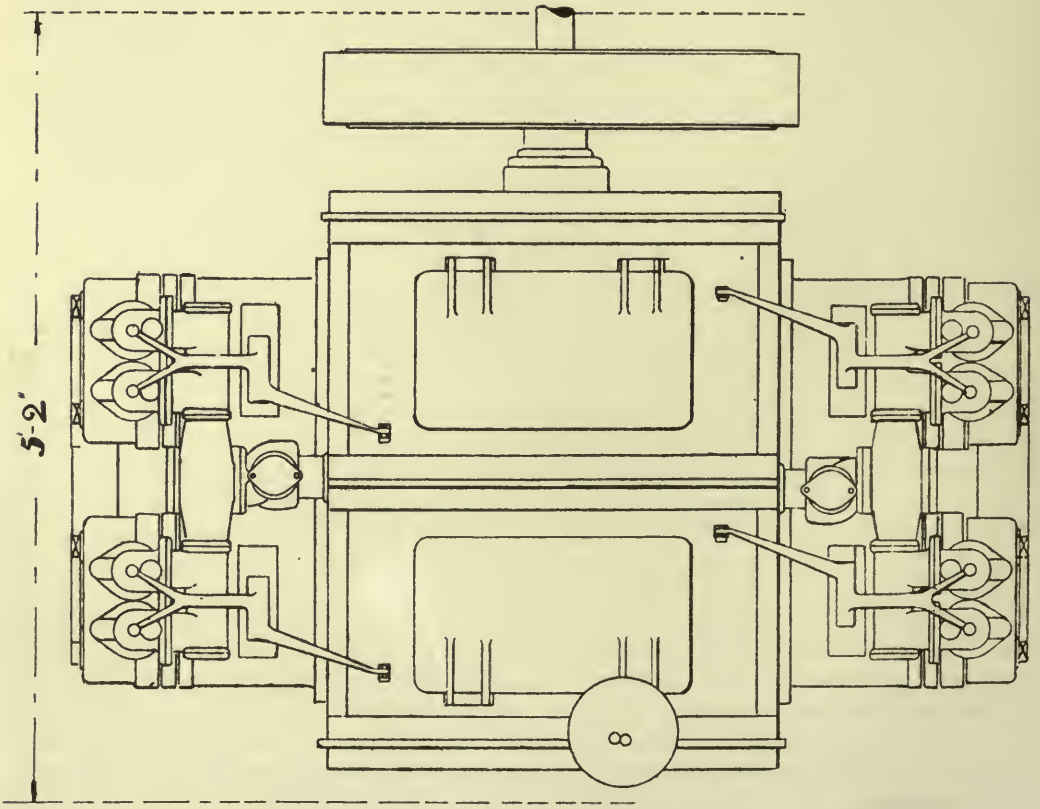


FIG. 12.—Plan of Wolseley 4-Cylinder Engine.

shall stand the rough usage of public service work, and the whole of the driving gear has been designed with a special view to keeping the maintenance charges as low as possible.

The latest type of "Wolseley" carburetter is fitted to the motor, and this ensures a very low consumption of petrol.

The motor has four cylinders placed in pairs opposed, and is shown in Figs. 11, 12, 13, an elevation plan and end view respectively. The bore is $4\frac{1}{2}$ inches, and the stroke is 5 inches. This will develop about 24 brake horse-power at 800 revolutions per minute. The crank shaft is carefully balanced to reduce vibration. The fly-wheel is 18 inches diameter, much heavier than usual, and is mounted on the end of the crank shaft on the off side of the car. It has the inside of the rim coned to receive the leather-faced friction clutch, or other approved make of friction clutch, as the contractors may decide to be suited to this class of work, which carries the "Renold" chain wheel. The crank shaft is of the best quality cast steel, and all parts of the motor are of the finest possible

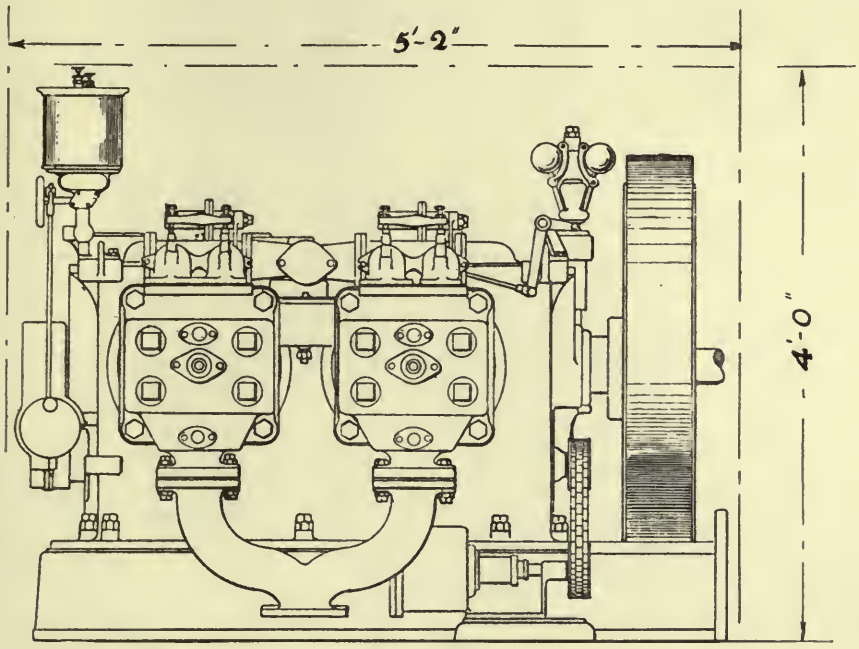


FIG. 13.—End View of Wolseley 4-Cylinder Engine.

material to ensure long life. The exhaust valves are placed in the lower part of the combustion chambers, and are mechanically operated and returned by laminated springs. The induction valves are automatic, and are entirely enclosed and have flat seats. The carburetter is of the latest type now being used on "Wolseley" 4-cylinder cars. The mixture pipes are of ample diameter, and arrangements are made for supplying either hot or cold air.

The gear box is of aluminium, having three point suspension. The gears are of high grade steel case hardened, and give four speeds forward and one reverse, all operated by one lever, the highest gear being in operation when the lever is right back. The gears will be changed with the usual cam arrangement, and will have speeds between $3\frac{1}{2}$ miles per hour, the lowest, and 17 miles per hour. This will enable the car to run up to the new legal limit when necessary with ease.

Suitable tooth sprockets are provided on the rear wheels and on the auxiliary sprocket shaft. The "Renold" silent chain, which forms the first drive, is 1 inch pitch and 2 inches wide. All the side chains are of roller type. Long life is assured to all the

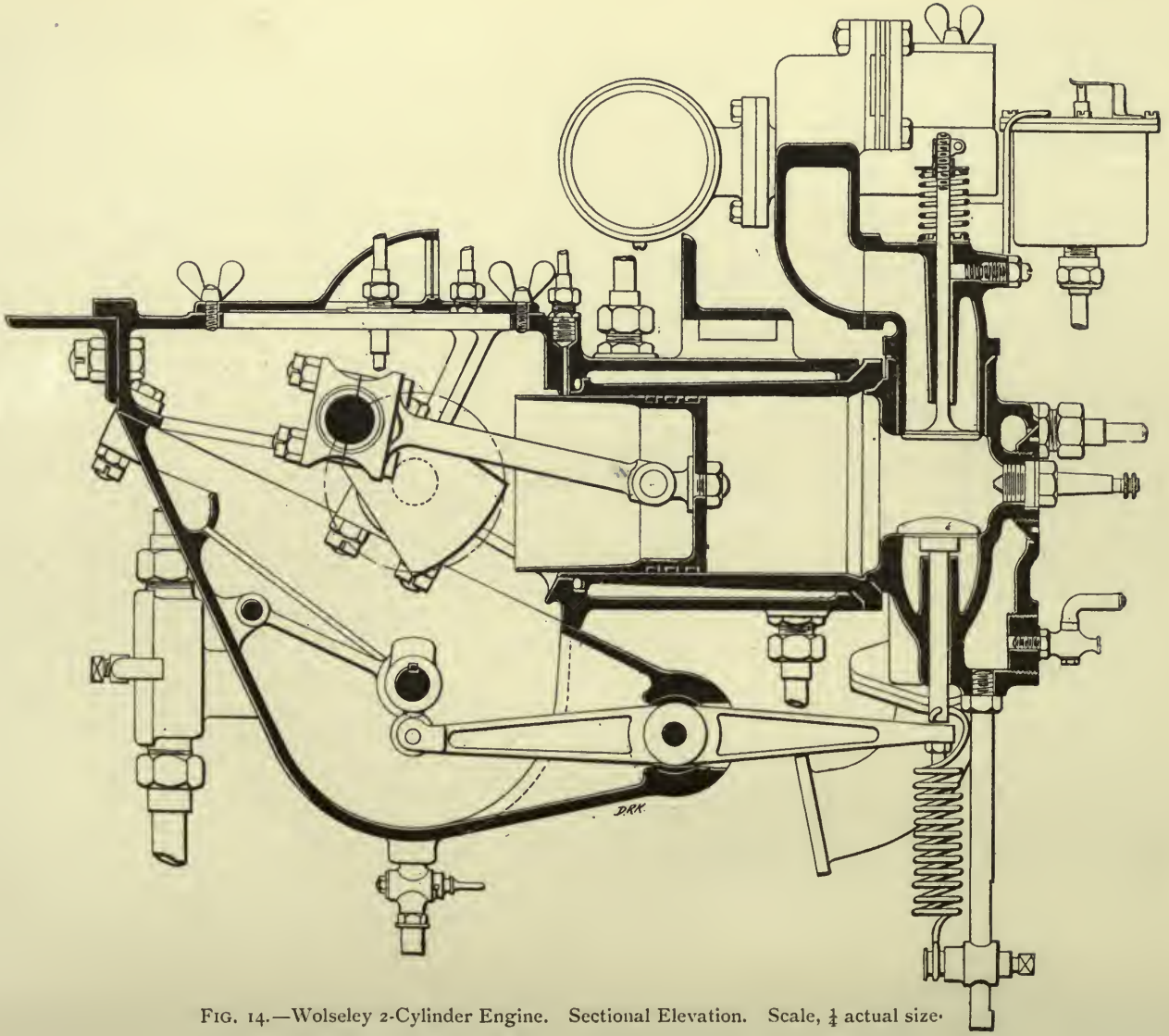


FIG. 14.—Wolseley 2-Cylinder Engine. Sectional Elevation. Scale, ¼ actual size.

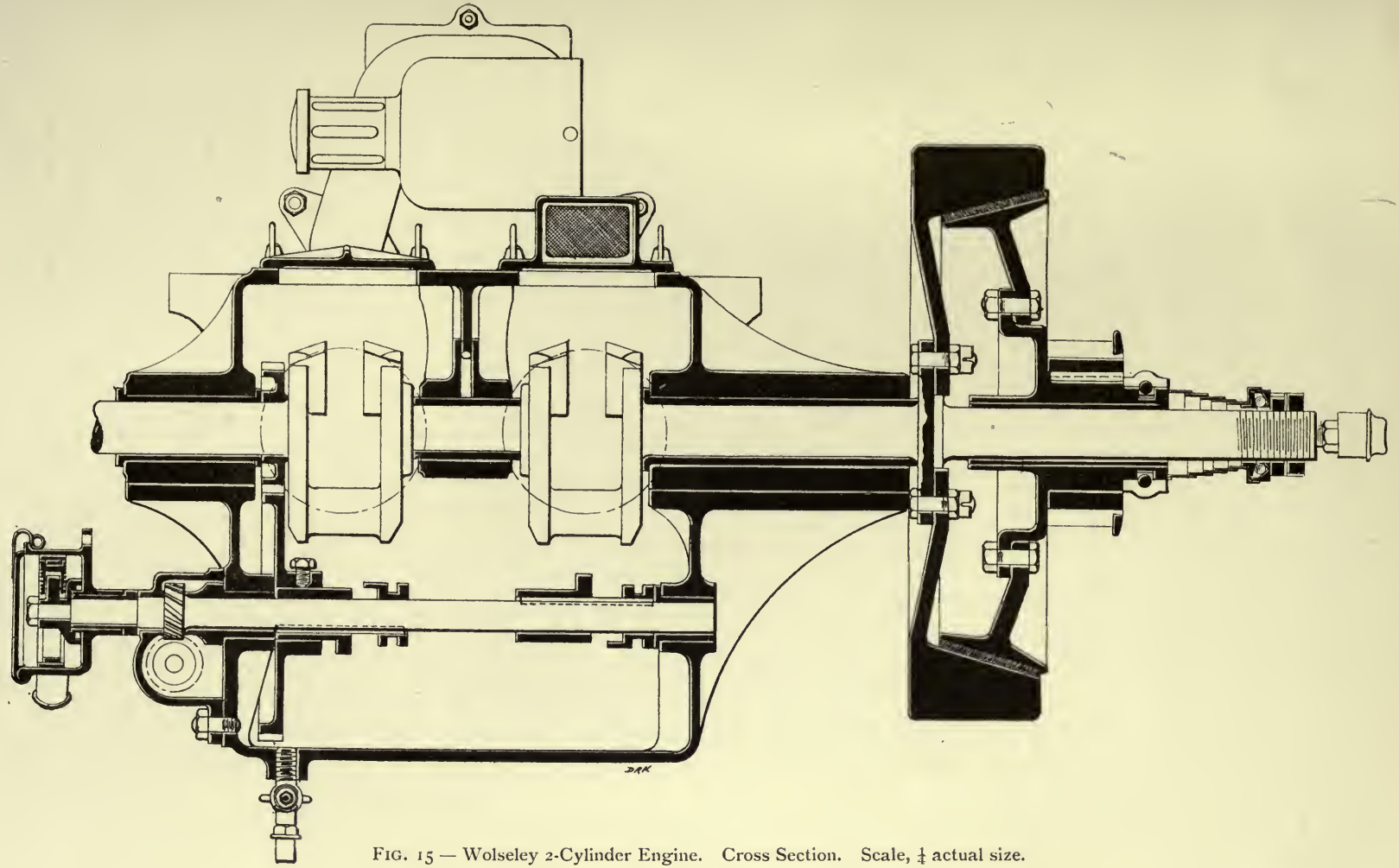


FIG. 15 — Wolseley 2-Cylinder Engine. Cross Section. Scale, ¼ actual size.

side chains by the adoption of the double chain drive. The first drive is entirely cased in, and this double arrangement permits the use of large sprocket wheels in all cases. This arrangement also precludes the necessity for fitting a very large sprocket wheel on the driving wheels themselves.

Two powerful brakes are fitted, a foot brake operating cast-iron expanding rings inside drums on the sprocket of rear road wheels. This brake is equalised to both sides of the car, and acts equally well in either direction. The side brake lever operates double acting equalised band brakes on the outside of the drums on the sprockets of the rear road wheels.

The oil reservoir is placed on the dashboard, separate pipes with independent sight feeds leading to all important bearings. The radiator is carried in the front between the front spring horns, and is of approved type. Cooling is arranged for by means of a powerful draught of air induced by a fan placed immediately behind the radiator, and driven by the engine. An efficient silencer is fitted with auxiliary pipe to ensure silence.

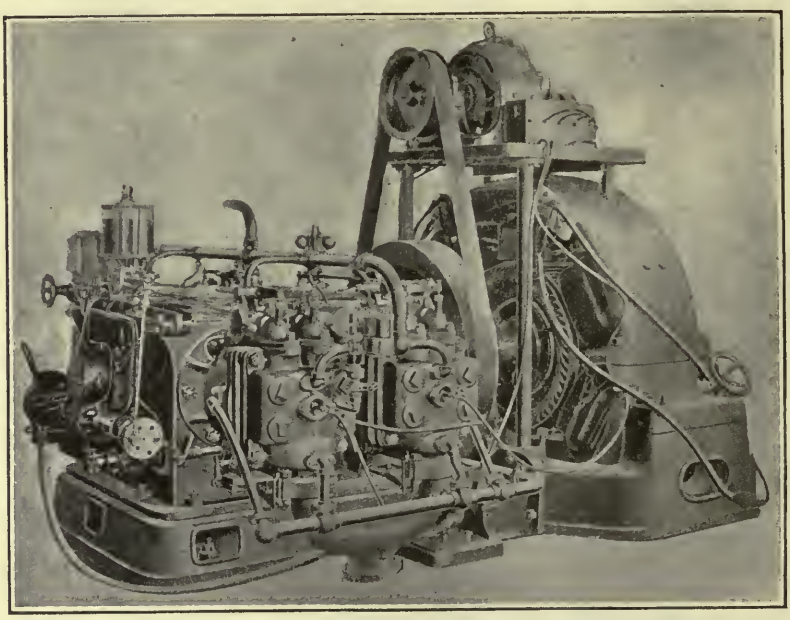


Fig. 16.—Wolseley Engine and Dynamo for North-Eastern Railway.

The bus will weigh approximately 2 tons. If necessary, however, it is anticipated that this weight can be considerably reduced. This motor bus is one among many now in use; it is a system of road traction of very considerable importance, and at present is being tried in London and in several provincial towns.

The introduction of street railways run by electric trolley system has compelled the steam railway authorities to consider other means of working short lines and suburban traffic than by means of heavy steam locomotives and carriages. The North-Eastern Railway have converted a short line to electric traction, and have also experimented with petrol motors with electric transmission of the power from the motor to the carriage axles by means of a dynamo driven by the petrol motor, and electric motors geared to the car axles.

The North-Eastern Railway Company had originally cars with vertical engines, but they were not found suitable for the work, and have now been replaced by petrol motors of the Wolseley type, which are horizontal. The first of the new type shown in Fig. 16 has recently been completed and put into service; the trials at full power showed that

the consumption of petrol worked out to only 0.78 pints per indicated horse-power per hour.

The engine has four horizontal cylinders 8½ inches in diameter and 10-inch stroke. On test it developed, at 400 revolutions per minute, 92 brake horse-power, and when accelerated to 480 revolutions gave well over 100 horse-power, at which the consumption was 0.78 pints per horse-power. The mean effective pressure in the cylinder, as calculated from the brake horse-power, without allowing for frictional losses, was therefore 80.3 lbs. per square inch.

The car (Fig. 17) shows the compactness of the arrangement. The four cylinders are overhung on a stiffly constructed cast-iron crank chamber, the inspection covers being on top, and the oil trough beneath. The engine has a 3-foot fly-wheel, through which it is coupled direct to the 60-kilowatt Westinghouse electric generator. The small exciter is driven by a belt. The current from the dynamo drives electric motors coupled to the axles of the car.

Forced lubrication is used for all the main bearings. All the valves, both inlet and exhaust, are mechanically operated by cams on the two cam shafts, one each side of the engine. These cam shafts are driven by means of spiral gear and lay shafts from the crank shaft. A very efficient silencer has been provided, and although this renders the exhaust from this large engine not much more audible than on a small touring car motor, the indicator diagrams, we have seen, show that there is little back pressure. The engine is governed on the throttle, and auxiliary gear is fitted, enabling the driver to hand throttle the engine from either end of the coach. Ordinary accumulator and induction coil ignition is used with a new type of commutator. The approximate weight complete is 35 cwts.

The question between this system and that of the trolley system is a large one, and at present sufficient data from practical results are not available to settle it. The general question will be discussed later when all the systems have been described.

The engines of the motor bus and the railway car are selected as good examples for heavy work with petrol, and as an intelligent departure from the conventional motor car motor.

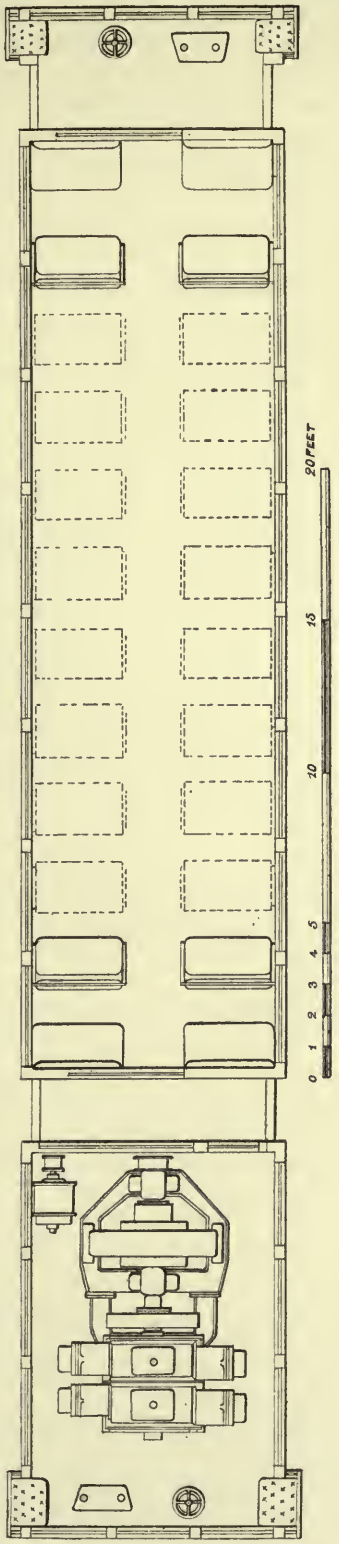


Fig. 17.—Petrol Electric Car on North-Eastern Railway.

A NEW PETROL LOCOMOTIVE

This locomotive is shown coupled to trucks on the railway, in the Frontispiece of this volume. It has been designed and built by The Maudslay Motor Company Limited of Parkside, Coventry, to the order of the City of London Corporation, for the special

purpose of drawing trucks between the Corporation Meat Market and the London, Brighton, and South Coast Railway sidings. The full load consists of four trucks, weighing when loaded about 50 tons. The maximum gradient is exceedingly stiff, being 1 in 36. The rails are of standard gauge. As the line to be traversed runs partly through the streets and partly in the market, the locomotive is geared to travel at a slow speed only, and has two speeds in each direction of 2½ and 5 miles per hour respectively.

The motor is similar in design to the Maudslay Motor Company's standard pattern, and has three cylinders, 9-inch bore by 9-inch stroke, and develops 80 brake horse-power at 450 revolutions per minute. Half-compression cams are fitted, and for greater convenience an 8 horse-power single cylinder engine is fitted for starting purposes.

Westinghouse brakes are fitted in addition to the ordinary hand brakes, also a sanding apparatus for use when the streets are greasy.

The water and petrol tanks are of sufficient capacity for a whole day's work, and the motor is cooled by a large tubular radiator fitted with a fan. The mechanism is all covered in from view to conform with Board of Trade regulations. The weight of the locomotive complete is about 12 tons.

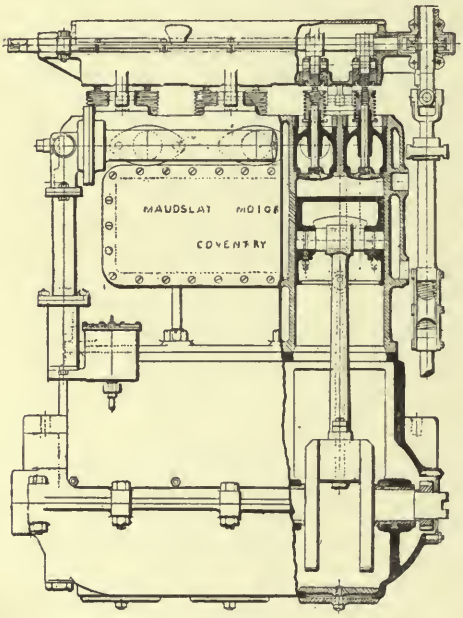


FIG. 18.—Sectional Elevation.

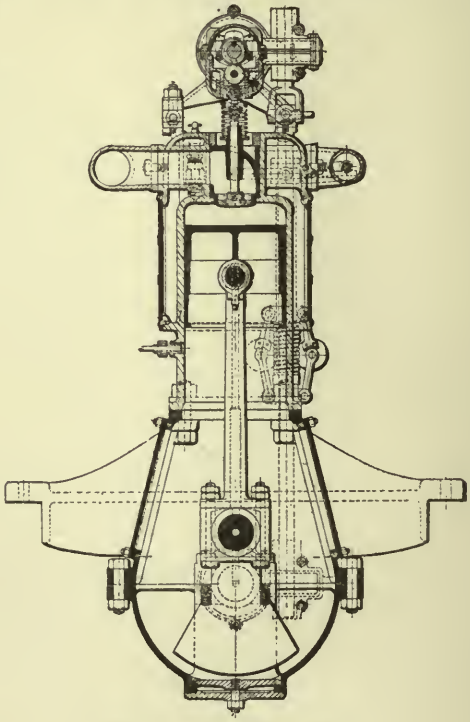


FIG. 19.—Cross Section.

Maudslay Engine.

The official trial of this locomotive took place on 29th February. The trucks were loaded with paving stones to bring them up to the contract weight (50 tons). The locomotive drew the train all over the system with perfect ease, and it was evident to those present that it would have been capable of drawing the same load at a much higher speed, or a much heavier load at the same speed. The trial included stopping and restarting on the steepest gradients. The running of the locomotive, and especially the ease with which it was controlled and reversed, gave complete satisfaction to all parties concerned; and those present to watch the trial signified their entire approval.

The Maudslay engine is shown part in section longitudinally in Fig. 18, and in cross section in Fig. 19, from which it will be seen the valves open direct into the

cylinders over the top of the pistons. The hinged counter shaft gives immediate access to the valves. The exhaust and inlet valves are interchangeable. The crank case has large inspection doors, through which all the main bearings and connecting rod ends can be examined and adjusted, and the connecting rods and piston bodily removed. Electric ignition is used. The lubrication is well attended to. The crank shaft is drilled hollow, and oil is forced through it by a pump into all the bearings, and the gear in the gear casing is similarly fed with oil by a force pump.

The governor, as will be seen in the cross section, is carried on a vertical shaft which connects the main shaft with the cam shaft, and throttles the air and petrol to the correct extent at all engine speeds. Cooling is by water pipes exposed to the air without a fan blast.

MOTOR WAGGONS

Fig. 20 illustrates Thorneycroft's chassis for their 2-ton petrol waggon. The engines are those already described under Gas and Oil Engines, Volume II., and generally

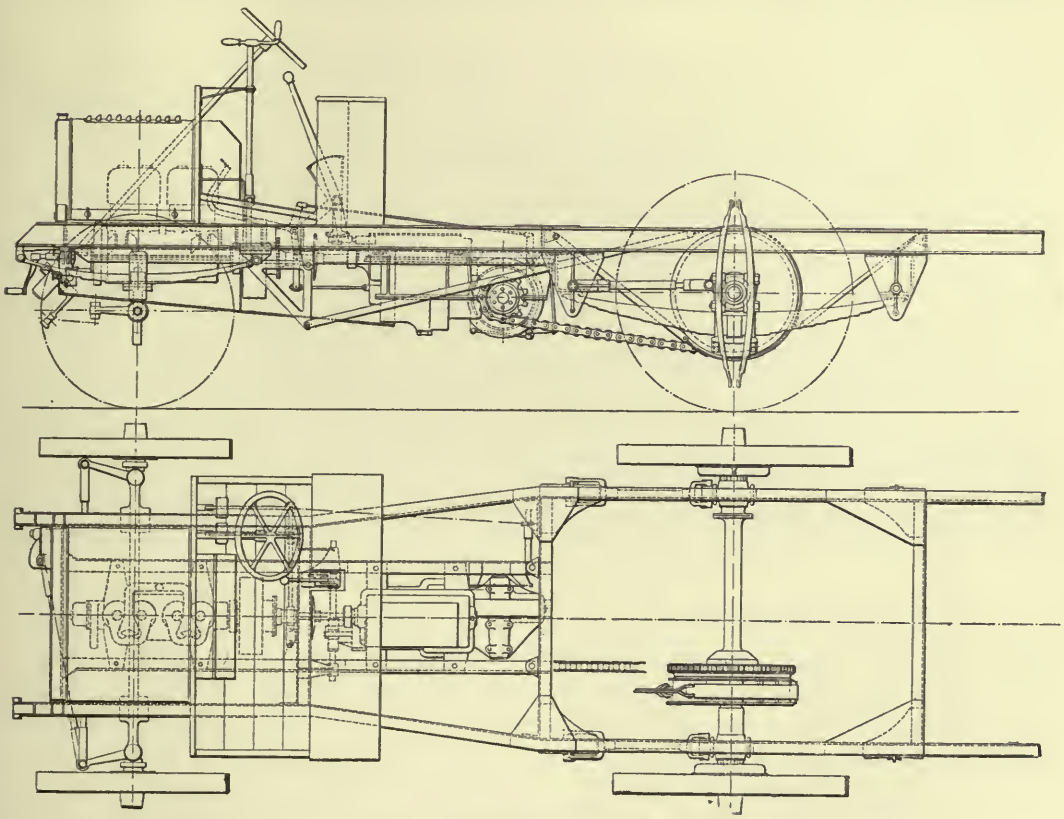


FIG. 20.—Thorneycroft Petrol Waggon.

the gearing is much the same as that for the usual type of autocars, only heavier. The engine is called a 20 horse-power motor. The gear box provides four speeds forward of $2\frac{1}{2}$, 5, $7\frac{1}{2}$, and 10 miles per hour, and one reverse speed of $2\frac{1}{2}$ miles per hour. All speeds are operated by one hand lever, which is placed to the left of the driver. This lever, by means of a side pressure, is made to engage in either of three racks projecting through the side of the gear pot; the inner ends of these racks are attached to the sliding spur wheels. The two racks not in mesh with the quadrant are held by an automatic stop-plate, which makes it impossible to get more than one gear in mesh at one time.

The power is transmitted from the gear-box to the back axle by means of a chain, this method being found quite suitable for loads of up to 2 tons. Above 2 tons a chainless transmission is employed. In order to relieve the spokes of the wheels of all driving strain, a Thorneycroft patent spring drive has been adopted. This consists of a pair of semi-elliptic springs, bolted to a square on the driving axle; the outer ends of the springs engage in two stops on the felloes of the wheels, so that the latter are driven entirely through the springs. This arrangement also absorbs sudden jars, due to bumpy roads, etc., which are transmitted through the wheels, and thus are not communicated to the mechanism. This feature is of special advantage where a chain drive is used.

A powerful foot-brake is applied to a drum on the gear-box counter-shaft. It is so arranged that no additional pressure is produced on the counter-shaft bearing when it is applied, there being a purely torsional effect. This is an improvement on the ordinary form of brake, with which there is considerable side pressure on the bearing of the drum when applied. The springs on this vehicle are particularly long and flexible; the rear ones, being attached to the under side of the axle box, bring the platform conveniently low for loading.

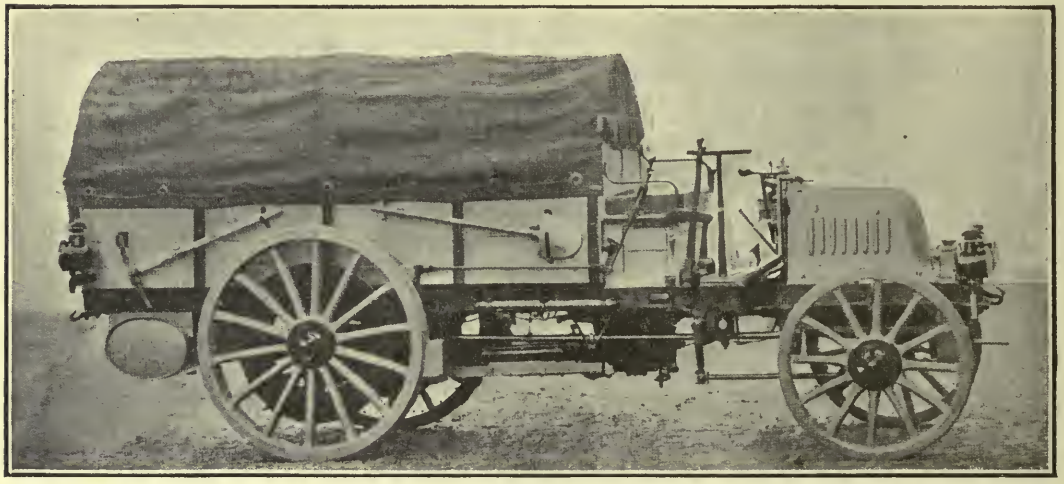


FIG. 21.—Military Petrol Waggon.

A German military motor waggon, built by the Daimler Motor Company of Wurtemberg, is illustrated complete in Fig. 21. This waggon on delivery made 435 miles through roads under snow in 10 days. It is driven by tooth-wheel gearing.

The following are some leading particulars:—

Distance between wheels	5 ft. $0\frac{1}{4}$ in.
Weight in working order	5950 lbs.
Useful load carried	5510 lbs.
Wheel base	10 ft. $4\frac{3}{8}$ in.
Height of inside flooring above ground level	3 ft. $3\frac{3}{8}$ in.

The greater part of the load is carried directly over the rear driving axle; the motor is in front, over the front axle. The lorries are driven by a 4-cylinder benzine motor of 12 to 14 horse-power. The motor-cooling device contains a water tank; the latter is fitted inside with coils formed of small tubes, through which a current of fresh air produced by a ventilator is made to flow. $26\frac{1}{2}$ pints of water last for one day's journey, without filling up, and this would be a feature of special advantage in war time. The motor and all bearings are automatically lubricated, the lorry carries an ample

provision of oil; the lubricating apparatus being in front of the driver, its action can easily be regulated.

The car is driven from the motor by four pairs of spur-wheels, of which one pair always remain geared; four different speeds are therefore obtainable. Backward motion is given by inserting an intermediate wheel. In those cars which are driven throughout by toothed-wheel gearing on the rear axle, the toothed wheels revolve in oil in a tight casing. The front axle is pivoted, and the car is steered by working a worm of wheel-gearing, which causes the axle to turn in the required direction. A foot and a hand brake are provided; the former acts upon the gearing, and the latter upon the hind wheels.

The cars in question run at a maximum speed of 8 miles an hour, and can mount gradients up to 1 in 5.

Both these examples are worked by oil spirits. Benzine, gasolene, or petrol in cold climates would be safe enough; but high flash oils alone are possible in Africa, India, and other hot climates. It seems that here also there is a field for the introduction of portable gas producers, for, if anywhere, it is in military waggons a solid fuel would be desirable.

The subject of heavy traction by internal combustion engines on road and rail has not received the attention it deserves, but no doubt by and by, when the possibilities and limitations of the electric schemes are practically demonstrated, engineers will turn their attention to direct driving by internal combustion engines.

The steam boiler has always been a heavy burden and a fruitful source of trouble in all traction engines by road or rail, and the future traction systems must take into account the internal combustion engine with oil fuel and with producer gas.

Electricity has no possible chance in the competition, except on rails and for limited distances; and then only acting as a transmitter of the power from a gas or steam engine.

CHAPTER III

AUTOCAR ENGINES

By this term it is hard to say what is all included. It is only certain that it includes the oil, petrol, and steam prime movers on light road vehicles for racing and passenger carriage. The nomenclature of the science and art of road locomotion requires revision and settlement very much. A glance through the technical journals dealing with the subject of road locomotion reveals an amazing amount of confusion in terms applied to the cars, the engines, and so on. The whole assemblage of a complete car is variously styled an Autocar, Motor Car, Automobile, Horseless Carriage, Locomobile, Power Carriage, and, most atrocious of all, a "Motor."

The word "motor," by long use, is synonymous with prime mover to ordinary engineers, but it is often applied to the complete power carriage by some, by others it means the prime mover. It is a term which should be strictly limited to the prime mover, and should be qualified by the words, petrol, oil, steam, or electric, as the case may be. The choice of name for the complete car lies between autocar, motor car, or power carriage. Autocar is one word, and not readily confounded with other terms, and seems to have the advantage; it will therefore now be adopted in this work, and qualified by the words petrol, oil, steam, or electric, as the case may be. The coach-builder's part of the car may be called the car body; it is a part we have little to do with in this work. The under frame carrying the motor and all its dependent mechanism has been called the "Chassis," and the term is worth retaining.

As a rule, the other parts of the machine go by their accustomed names as of old, without any additional autocar jargon.

The essential parts of an autocar are few and simple; but the tendency of the commercial section of those engaged in the exploiting of the autocar has been to complicate it considerably by additional parts and intricate inventions, supposed to be improvements. One uses two cylinders, another puts on three, and another goes one better by using four, and yet another goes the whole hog and employs six or eight cylinders without any rational design. Then we find some one with a marvellous arrangement of crooked tubes, enveloped in what he calls gills, supposed to cool the water for the cylinder jackets. Then another brilliant genius adds a pump to circulate the water, the gilled pipes are termed a condenser or cooler. Another expert comes along with an air fan to cool the cooler; then the vast field for improvement in igniters, carburetters, brakes, gears, etc. etc., keeps hundreds of autocar enthusiasts busily ringing the changes on the ancient inventions. It would be impossible to notice every car and all their different motors, and it would be useless if we could, for the essentials for good cars are not many, and their principles easily understood. First, then, we shall consider the fuel question for autocars. In this case cost is not of great importance. People who can keep autocars are like those who can keep horses and carriages, pretty well able to pay for the luxury, and they will use that fuel which gives them a reliable engine and takes

little space on the car, producing little or no smoke or dirt. Petrol seems at present to be by far the best fuel for their purpose. But the supply of petrol is limited and in a few hands; it is therefore liable to be "cornered." Only about 2 per cent. of the world's supply of crude petroleum is available for the production of motor petrol spirit. The rapid increase in the number and size of autocars has increased the consumption of petrol enormously in America; the growth has been so great that the petrol produced there is all required for home consumption, so that unless some fresh supplies are discovered the price must go up. Hence this fuel question is one which the autocar industry must face. It is also an important question for the War Office and the Admiralty in their use of autocars, submarine boats, or petrol war-ships of small size. In time of war the supply would undoubtedly be cut off, as it is not a British product. Paraffin oil is a British product of some magnitude in Scotland, so that for war purposes it would be saner and safer to adopt oil motors. But an interesting question arises as to whether alcohol would on the whole not be a better substitute. This fuel can be produced from agricultural products grown annually, so that a supply could be relied upon in our latitudes every year as long as the sun shines and water runs. Scientific men have long ago come to the conclusion that in alcohol we have the only substitute for natural fuel; that it is not used in this country for autocars is due to the fiscal authorities. Alcohol is heavily taxed in order to collect a large revenue from the drink trades, but there should be no difficulty in altering the laws in order to allow of the sale and use of alcohol for motor purposes, without the heavy tax; this has been done in Germany with beneficial results to all concerned. In 1887 the cost of alcohol in Germany was 4s. per gallon; and now by sound legislative laws it can be obtained at 9d. per gallon in 1500 gallon lots, 10d. in 40 gallon barrels, and 1s. 3d. in one gallon jars,—even at 1s. 3d. it is cheaper as a fuel than petrol at 1s. 6d. In view of this enlightened movement the inertia of the British Government in its conservative obstinacy in refusing relief is an object-lesson on the subject of the retardation of home trade by home influences. Agriculture would benefit by the introduction of alcohol as a fuel, for the money sent to the oil wells proprietors and the oil works would go to the farmer for raw materials. This, however, does not concern us, our question is—What is the true value of alcohol as a motive power fuel? This has been very fully answered by the research of Mr. W. R. Ormandy, D.Sc., from whose paper at the Automobile Club, 24th March 1904, the results are here given.

Owing to the relatively high price of the unsuitable methylated spirit sold in this country few attempts have been made to utilise it as a fuel in internal combustion motors. We have, therefore, to go to the Continent for our information with regard to the subject, and although the use of alcohol in motor cars has perhaps made more progress in France, yet the quantity of alcohol used as a fuel for motors in Germany is undoubtedly far larger than in France, owing to the fact that in Germany alcohol is looked upon more as a fuel for slow running motors of 20 to 30 horse-power, which, though smaller in number, are larger consumers. The first experiments in the efficiency of alcohol-driven motors were carried out in the year 1895 by Professor Hartmann. A motor made by Grob & Co. of Leipzig, for investigation by the German Agricultural Society, was tested as to its behaviour with both petrol and spirits. The consumption worked out at 426 and 839 grammes per brake horse-power-hour respectively. These correspond to efficiencies of 13.6 and 12.2—the former a fair result for a much more up-to-date petrol engine. Later in the same year a Körting motor, with a special vaporiser tested by Professor Slaby of Berlin, only consumed 550 grammes per brake horse-power-hour —a great advance. From 1897 to 1901 a number of makers constructed motors for use with alcohol which ran on a consumption of 390 to 440 grammes per brake horse-power-hour.

If the question be asked why alcohol was so long neglected as a source of power for

internal combustion engines when efforts were being made in every direction to find an outlet for the over-production which was taking place, the answer is to be found in a consideration of the relative heats of combustion of this substance compared with those against which it had to compete. It is near enough for our purpose to take the heat of combustion of alcohol as 5500, and of petrol and paraffin at about 10,250. At first sight it would appear hopeless to compare two such substances as a source of power unless the price of the one possessing lower calorific effect was approximately one-half that of the other. If the value of a fuel were measured by its heat of combustion, this would be the case; but fortunately it is not so. It depends on the number of calories which can be converted into work. In this respect it is interesting to follow the gradual development of German alcohol gas engine production. The solitary specimen above referred to showed at a brake test such a consumption that the efficiency was approximately 12½ per cent.; that is to say, 12½ per cent. only of the heat units conveyed into the machine were given out again in the form of work. If we compare with this the results of the comparative tests of the alcohol-driven gas engines entered in 1902, in the competition for the prize offered in that year by the German Agricultural Society, we learn what astounding progress has been made. Out of the ten machines entered in this competition no less than three gave efficiencies of from 32.7 to 30.9 per cent. when working on full load. This is an astonishing result, and it places the alcohol motor very high in the list as an economical machine for the conversion of heat into work. These tests were carried out by Professor Dr. Meyer of Charlottenberg, and are published in volume lxviii. of the *Arbeiten der Deutschen Landwirtschafts-Gesellschaft.* It must certainly be of interest to learn, as far as may be, to what these extraordinary results are attributable. In the first place, it is worthy of note that the degree of compression which was used, though very variable, was on the whole very much higher than that which it is customary to use for petrol-driven motors. In some cases a compression up to 10¼ atmospheres was used, and the greatest explosion pressure attained was in a number of cases as high as 33 atmospheres.

In order, as far as possible, to make the comparison between the various motors a fair one, Professor Meyer reduces the consumption of alcohol per brake horse-power-hour to a basis of compression of 8; that is to say, the clearance space in the motor was one-eighth of the total volume in the cylinder and clearance space together at the end of the suction stroke. This calculation is carried out by making use of certain assumptions with regard to the specific heat of the mixture, which, though not strictly accurate, are sufficiently near for the purpose in view. As showing that the numbers thus calculated are approximately correct, the following case is cited—that a Deutz motor, working on a compression of 5.91, showed a consumption of 436 grammes per brake horse-power-hour. If this be converted to a basis of 8.9 compression (which was that actually used in the motor tested in 1902), the consumption, according to the calculation, should be 377 grammes, whereas the actual amount used was 364. The agreement is at least sufficiently near for the purpose in view. From this it would seem that the higher efficiency of the alcohol motor is due almost entirely to the high compression which can be used. How comes it that this compression can be used in the case of alcohol, and not in the case of petrol? During the compression of a mixture of any fuel as vapour and air, heat is given out, and at a certain point the temperature attained by the mixture is such that explosion takes place. This point of automatic explosion fixes the absolute limit of compression which can be used. If the compression be carried beyond this point we get what is known as pre-ignition, that is, an explosion before the piston has reached the end of the compression stroke. Now the temperature which a mixture of gases attains upon compression depends largely upon the specific heat of the substance in the mixture. In the case of petrol this is very low; in the case of alcohol it is very much higher, and we have also to bear in mind that the spirit used in these experiments contained 10 per cent. of its

volume of water. That the influence of water is to allow of a very much higher compression is shown in the case of the Griffin motor, where by injecting water along with paraffin, compressions of over ten atmospheres were attained with safety, whereas without the water from four to five atmospheres is the permissible safe limit. A still more striking testimony as to the influence of water vapour in reducing the ignition point of explosive mixture of gases is shown in the case of the new Vogt motor, where, using coal gas and air in the presence of steam, it was found necessary to produce compression pressures of twenty-five atmospheres before self-ignition took place.

A study of Professor Meyer's work certainly leads to the conclusion that the increased efficiency of the alcohol motor is entirely due to the increased compression employed, and the possibility of employing this compression is due, in the first place, to the low inflammability of alcohol air mixtures, but, in the second place, and in a higher degree, to the water contained in the alcohol. The question might be raised—Why not use more water and a higher compression? This has been tried, and Mr. Exner of Vienna has been able to prove that by so doing there is an increased efficiency. Professor Meyer has shown that the addition of further water without a corresponding increase in compression has a disadvantageous effect. The maximum pressure of explosion is reduced, and the combustion is diminished in velocity; indeed, with a certain excess, the diagram points to comparatively slow burning rather than to an explosion. This latter result, obtained by Professor Meyer, goes far to prove that the increased effect is in no wise due to the presence of water after the explosion has taken place.

By increasing the compression we may use alcohol containing an increased percentage of water, and at the same time obtain better useful effect from the fuel, but the percentage gain, which is attained by compression beyond ten or twelve atmospheres, is so small that the greater uncertainty of ignition which accompanies it, and the added expense of constructing motors to withstand the accompanying high maximum explosion pressure, more than counterbalance it.

If the above conclusions are correct, the generally received idea that a petrol motor can be converted into an efficient alcohol motor simply by altering the curburetter is proved to be fallacious. It is true that the conversion of alcohol into a state fit for explosion requires other means than in the case of petrol. This is obvious, when we consider that the heat required for the evaporation of alcohol is about two and a half times as great as that for petrol, and we have further to bear in mind that there is 10 per cent. of water present, requiring five and a half times the amount of heat to evaporate it, compared with an equal weight of petrol. At first sight it would seem that this would be a serious difficulty in the utilisation of alcohol, but if we calculate the actual amount of heat which is necessary to evaporate a certain quantity of alcohol containing 10 per cent. of water, we find that it amounts to only $5\frac{1}{2}$ per cent. of the total heat of combustion of that same amount of alcohol (in calculating the heat of combustions, in all cases it must be understood that the heat which would be given out by the water vapour in the products of combustion condensing from the form of steam is not taken into consideration). This $5\frac{1}{2}$ per cent. of heat necessary to convert the alcohol into vapour can readily be abstracted either from the exhaust gases of the motor, or from the water taking away heat from the cylinder walls. We have here some resemblance to the chain of operations taking place in a modern blast furnace, where the waste gases from the furnace are now used to heat up the air fed to the bottom of the same, or in the case of a Siemens' regenerative furnace, where high temperatures and great economy are attained by a similar means.

By making use of the saturation equivalents of alcohol and water for air at various temperatures, it is possible to find out to what temperature the ingoing air into the vaporiser must be heated in order that the mixture of air, alcohol, and water passing

into the cylinder may be such that there is no necessity for any of the constituents to be in a state of suspension as liquids. We find that it is only necessary that a temperature of 190° C. should be attained. This comparatively high temperature is only required when the mixture entering the cylinder is to contain the maximum amount of alcohol which the oxygen present is able to fully consume. It is in all cases preferable to work with an excess of air, in order to make sure that combustion shall be as complete as possible. Of the ten motors entered for the competition before referred to, Professor Meyer found that the one which worked on the poorest mixture with the most economical results would require the ingoing air to the vaporiser to be heated to a temperature of 125°, in order to carry the alcohol and water in the form of vapour.

The above calculations are carried out on the supposition that the air which is used to start with is saturated with water vapour at a temperature of 15° C., a state of affairs not often attained even in this climate. It is also easy to prove, in those cases where the air is not warmed prior to entering the carburetter, that it is only necessary to heat the mixture of air and alcohol spray to a final temperature of 30°, in order to attain complete evaporation of the liquid ; that is to say, contact of the sprayed mixture with a sufficiently large surface at or over 35° C. to evaporate the liquid, and to give the mixed vapours a final temperature of 30° C. is all that is necessary.

Another circumstance which plays a considerable rôle in the efficiency of spirit-driven engines has been proved by Mr. Fehrmann to lie in the temperature of the water employed in the cooling jacket. It will be readily understood from what has gone before that the sudden introduction of the air saturated with alcohol and water into a cylinder with very cold walls will have the effect of condensing the fuel and leaving a poor mixture, and such is indeed the case. It has proved impossible to run some alcohol motors with their water jackets supplied at a temperature of 0° C. The great importance of this point, however, was not understood until Fehrmann showed that the amount of alcohol required in some cases to drive a motor on half load was 100 per cent. more when the water in the cooling jacket was kept at about 15° C. than when the jacket was kept at 100° C. This is a subject of very great importance, and all tests of fuel consumption in alcohol motors which do not take this into account will be of little or no scientific value.

A further interesting point brought out during the trials of the ten motors was the influence of varying strength of mixture on the consumption. Thus a motor nearly at full load, working on fairly weak mixture, and giving only 2.3 per cent. misses on the hit-and-miss governor, would have a certain consumption, whereas with the same load on richer mixture with a larger percentage of misses the consumption in some cases was as much as 16 per cent. higher, and this behaviour is not characteristic of spirit motors only, for Professor Meyer has observed the same thing in paraffin engines, where in one case the increase in consumption on the same load reached 24 per cent.

With regard to the general comparison of the properties of alcohol as a power-producing substance for motors, compared with petrol, it may be pointed out that the combustion of alcohol in the motor under full load is practically complete, and that the products of combustion are odourless, or nearly so. It has been stated that during the explosion of mixtures of alcohol and air, acid substances might be formed which would have a deleterious effect upon the substances of the cylinder and the valves. The Experimental Fermentation Institute at Berlin have alcohol motors which have been running for years, and in no case have any signs of such action been observed. Only in the case of a small motor, which is frequently running on very light or no load, it was found that the exhaust pipe was slightly sooted, owing most probably to the low temperature which obtained, and the consequent incomplete combustion.

In concluding this part of our subject we may say that, in so far as alcohol is less volatile, and has a higher ignition temperature, it is much less likely to be a source of accidental fires. Its storage need not be subject to the same stringent regulations, and

in its carriage it is not subject to the same severe restrictions. It is more pleasant to handle than either petrol or paraffin; it is homogeneous, which is more than can be said for the present supply of petrol. The composition of the later supplies of petrol is becoming more and more heterogeneous, and there is an ever-growing percentage of high boiling-point constituents, which will do their part, no doubt, towards adding to the unpleasant smell of the exhaust gases and in diminishing the already poor efficiency of the petrol engine.

If care be taken that the carburetter passes the increased quantity of air necessary for the oxidation of benzol compared with alcohol, and that the temperature of the fluid in the cylinder jacket is kept constant, it would seem that, *at any given compression*, equal efficiencies are obtainable, but the allowable compression is less the greater the addition of benzol.

That alcohol is not only a suitable motor fuel, but that in most respects it is the most suitable, is shown in the foregoing, and if further proof were needed as to its practical possibilities it can be gathered from the records of those French automobile trials in which alcohol was used, and in which trial through Amiens, Arras, Abbeville, and back to Paris, wherein nineteen heavy cars, sixteen light cars, six voiturettes, and six cycles competed. The distance of 453 miles was covered in about 23 hours on a consumption of 20.85 gallons by one car, and in 26½ hours on 18¼ gallons by another. Again, Mr. Farman, on a 35 horse-power Panhard, covered 254½ miles at a rate of 52.2 miles per hour, using alcohol as a fuel.

In Germany alcohol is rapidly superseding petrol and paraffin, so that in that country light cars will eventually all use alcohol.

We have already referred to the carburetters in Volume II. as an essential part of the petrol engine. This element has of late assumed alarming complications in some instances. The simple suction carburetters, no doubt, had plenty of room for improvements, and some have been much improved without much complication being added. We may refer to three of the later forms as typical. The idea is to make them self-regulating at various speeds of the engine, and to maintain the same proportion of air and fuel throughout the different variations in speed. In fact, two governing devices are required in a perfectly controlled engine: first, the automatic governing of the carburetter; and secondly, a throttle governor on the engine—the one to govern the mixture of air and fuel in their due proportion, the other to govern the amount of mixture supplied. The one makes up the mixture according to prescription, the other measures out and administers the dose as required.

THE CARBURETTER

The combined governor and carburetter employed upon the Brooke autocar is shown in Figs. 22 and 23, the former illustration being reproduced from a photograph, and the latter being a longitudinal cross section. The carburetter is fixed on the right side of the engine, and the main air supply is led to it by a pipe passing across between the cylinder castings from the neighbourhood of the exhaust pipe.

The carburetter proper is of much the usual float-feed type, and is rendered automatic —in order to enable it to maintain a constant richness of mixture—by providing it with a spring-loaded air valve, which tends to prevent any considerable increase in the degree of vacuum that is formed in the mixing chamber at any time. The float-feed chamber A communicates with the spray jet B, as in most carburetters, and a combined mixing cone and inspection plug C is screwed into the mixing chamber immediately above the jet. The warmed main air supply enters through the pipe fitting F, and cold air can also be drawn in to a greater or less extent through the valve D_1 in the casting D. The whole of the air then passes around the jet, and it can then normally find its way to the induction pipe E through the hollow throttle-valve piston G. The valve D_1 is

normally held on its seat by a light spring, the strength of which can be adjusted by the feed screw D_2. When the engine is running very slowly, or is only being started, the whole of the air drawn by the engine enters the mixing chamber through the pipe fitting F, the size of which is so proportioned that sufficient petrol is then drawn up through the jet to give a rich enough mixture. When the engine speed is higher a greater degree of vacuum would naturally be formed in the mixing chamber, and too much petrol would flow through the jet. The valve D, however, then automatically opens, and the mixture is thus prevented from becoming too rich.

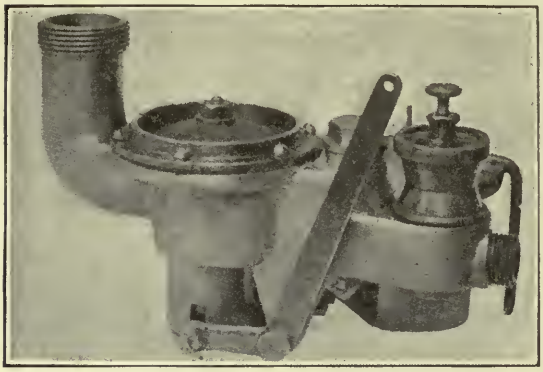


FIG. 22.—The Brooke Carburetter.

The piston G, which acts as a throttle valve between the carburetter and the engine, is normally held open, as seen in Fig. 23, by a spiral spring lying beneath it. A second, hand-controlled, piston H is fitted into the lower portion of the same cylinder, and it is on this second piston that the spring rests. The piston H is connected with the lower of the two small hand-levers above the steering wheel on the car, by a system of levers of which H_1 and H_2 form a part, as seen in Fig. 23. The driver is by this means able to regulate the pressure of the springs between the pistons H and G, and normally tending, as we have seen, to hold the throttle valve full open. The piston G is fixed securely to a diaphragm J, which lies above it, and this diaphragm constitutes a portion of the wall of the induction pipe between the throttle valve and the engine. Whenever the suction in the induction pipe increases, the tendency is for the diaphragm J to be pressed downward by the atmospheric pressure on its external surface, and the tendency, therefore, is for the piston G to slide downwards, cutting off the feed from the carburetter to the engine. The diaphragm J, together with the piston G, therefore, acts as an automatic governor, and tends to maintain a constant engine speed because the degree of vacuum in the induction pipe increases as the engine runs faster. The normal speed of the engine depends upon the position of the lower piston H, and can therefore be adjusted from the driver's seat.

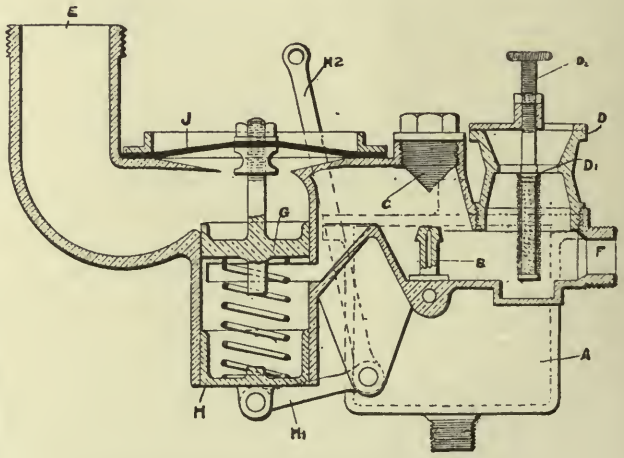


FIG. 23.—Section of Brooke Carburetter.

Another excellent form of carburetter is that employed on the Hutton chassis. This carburetter differs in many important respects from others that are now on the market, notably in being made entirely of aluminium, but chiefly because no attempt is made to maintain a constant degree of richness of the mixture. The construction of this carburetter is well shown in Figs. 24 and 25, in the former of which the various parts of one of them are shown separately, and in Fig. 25 the mechanism is shown sectionally.

The main casting A contains the annular float A_3, which regulates a valve in the

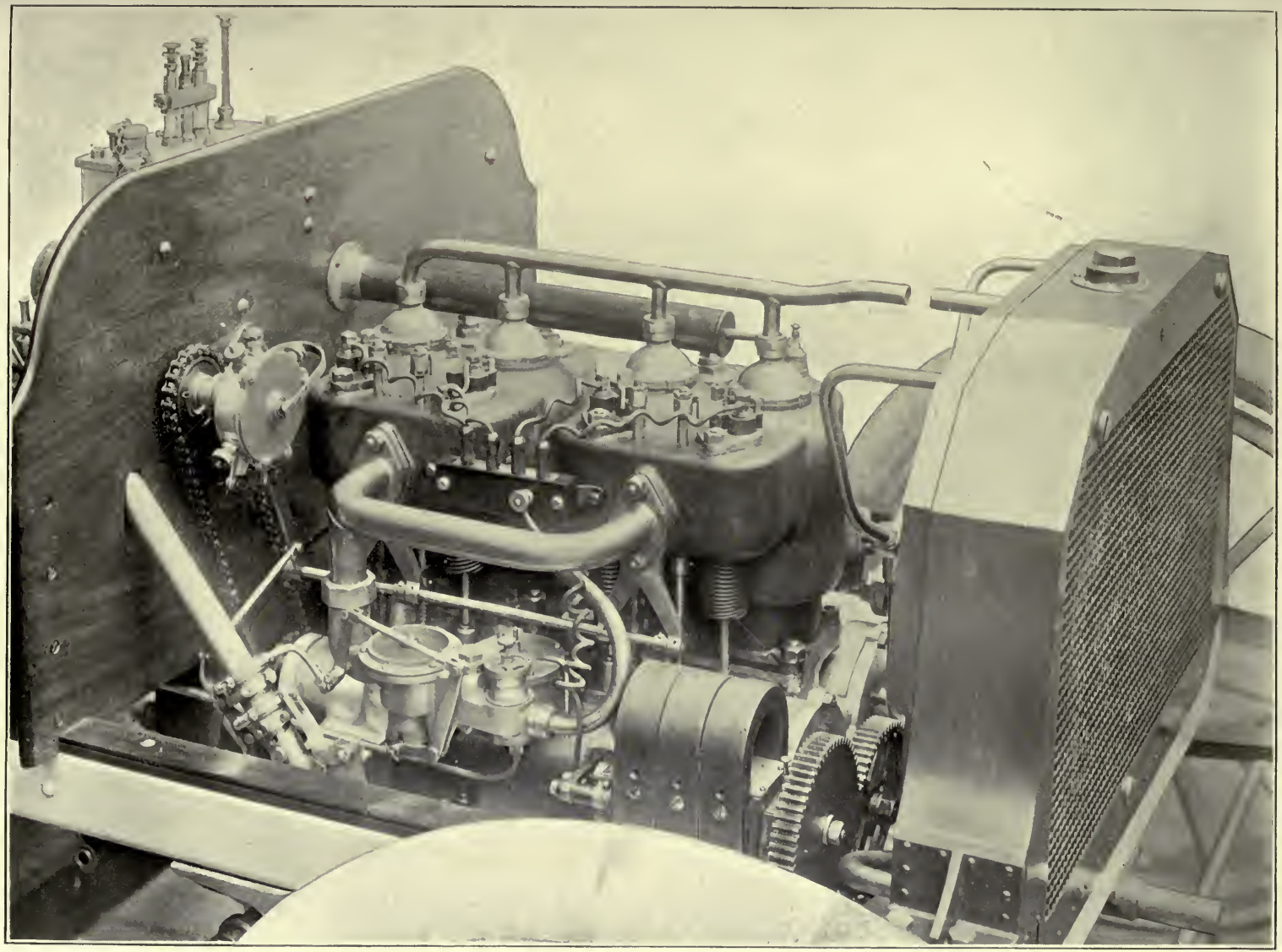


PLATE I.—VIEW OF AUTOCAR PETROL ENGINE AND ACCESSORIES.

base in much the usual way, controlling the flow of petrol from the fitting A^1 beneath it. The petrol is led into the fitting A_1 by the pipe connection A_2, and it will be noticed that a large gauze filter is arranged so that the whole of the petrol has to pass through it. The portion A_1 forms a large chamber beneath the filter, so that there is quite a large space for any foreign matter or water that may enter with the petrol to settle, and these can from time to time be drawn off by a cock which is screwed into the bottom of it. Another casting A_4 is fitted immediately above the float-feed chamber, and a portion of it projects down to form a central boss inside the float. Inside this projection, the spray jet A_5 is inserted from beneath, so that the jet is not only very readily accessible, but is in unusually direct communication with the petrol in the float chamber. The jet is surrounded by a sleeve A_6, which screws down from above through and into the casting A_4, so that it leaves a space for air between itself and the casting A_4 above the level of the jet. The sleeve A_6 is slotted opposite to the jet, so that the air can find its way into the sleeve through these slots.

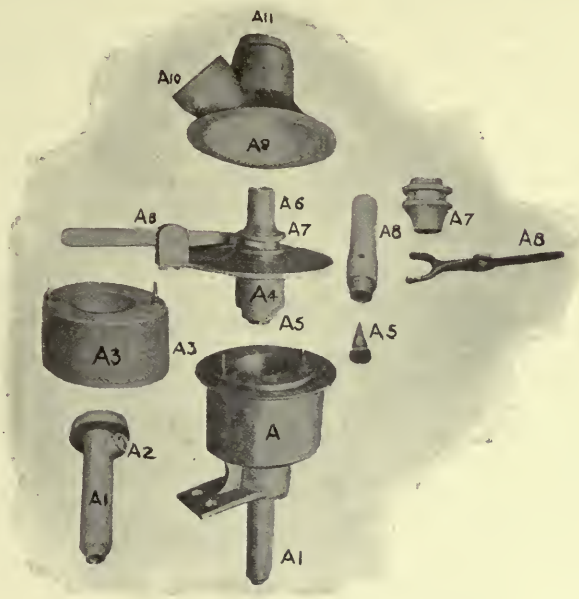


FIG. 24.—Parts of Hutton Carburetter.

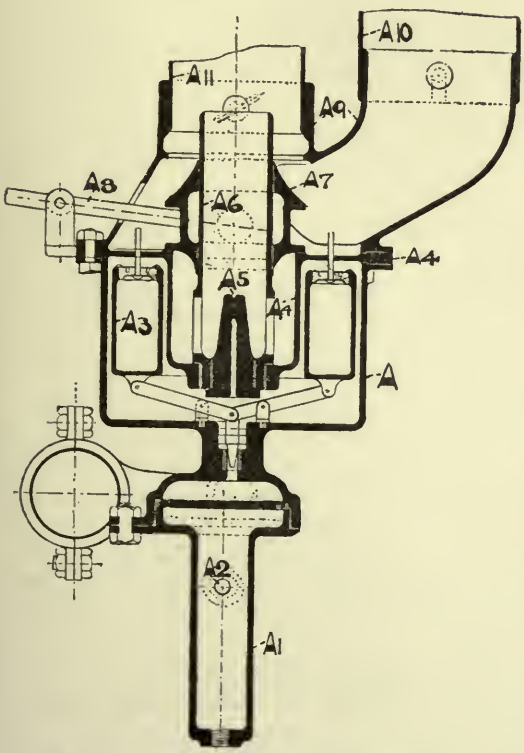


FIG. 25.—Section of Hutton Carburetter.

Outside the upper portion of the sleeve A_6 a sliding valve member A_7 is fitted, and this can be moved up and down by a pivoted forked lever A_8 that engages with a groove in A_7, and is externally connected with the governor on the engine and with the accelerator pedal on the car.

Above the casting A_4 is fitted another casting A_9, the shape of which is clearly shown. This casting A_9 receives two pipes, the one fitting into it at A_{10}, conducting the warmed air supply to the carburetter, and the other at A_{11} being the induction pipe to the engine. The passage leading to the latter lies centrally above the sleeve A_6, this sleeve projecting up into it. It will be noticed, therefore, that the valve casting A_7, when moved upwardly, tends to close the direct passage through A_{11} to the induction pipe, and that when moved downward it allows a full direct opening to this passage, but then commences to close

the passage leading down between the sleeve A_6 and the casting A_4 to the inside of the sleeve A_6 and to the jet A_5. By moving the valve A^7, therefore, the relative proportion of air which ultimately reaches the induction pipe, either direct from the passage A_{10} to the passage A_{11}, or less directly past the jet A_5 and up the sleeve A_7, is varied; and since it is only the air which passes the jet that is carburetted, it therefore follows that the richness of the mixture drawn into the cylinders of the engine can be varied by this control. The governor is so connected with the lever A_8 that, as the speed of the engine increases, the tendency is for the valve A_7 to be moved downwards, thus causing the richness of the mixture to be reduced, and finally—if the speed were to increase sufficiently—causing the engine to draw pure air only. It will be seen, too, that when the engine is at rest, the valve A^7 closes the direct communication for the "auxiliary" air, and that therefore, when starting the engine, the necessary extra rich mixture is always obtained.

It is pointed out, in connection with this carburetter, that by arranging an annular float in this way, the level of the petrol in the float chamber is entirely unaffected by the level of the road surface on which the car may happen to be, whereas with most carburetters the height of the petrol in the chamber tends to vary, either when the car is going up or down hill, or when it is running over roads having a changing cross section.

Another claim made is, that a higher fuel efficiency results from the employment of this carburetter, and from the system of controlling the speed of the engine, by varying the richness of the mixture, instead of by throttling—it will be noticed that no throttling of any kind is introduced by the sliding valve A_7.

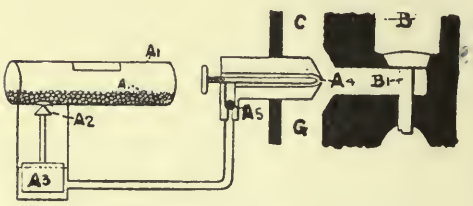


FIG. 26.—Chenier and Lion Carburetter.

Solid carburetting materials have not been much used, but in some cases they may be of considerable advantage. One has been introduced by Chenier and Lion, employing naphthaline, which is solid at ordinary temperatures but easily liquefied.

Fig. 26 is a diagram of the carburetter of their patent. The naphthaline A is contained inside the receptacle A_1, which corresponds to the petrol tank of an ordinary automobile. An enlarged mushroom valve A_2 is mounted on the top of the vertical rod which terminates below in the float A_3. It will be understood that the parts here shown are exhaust-jacketed, and the motor is in the first instance started with ordinary petrol until sufficient heat has been obtained to liquefy the lumps or balls of naphthaline as they fall down through the mushroom valve into the float chamber below. When the melted naphthaline attains a certain level, the mushroom valve A_2 is, of course, automatically closed, and prevents a further supply of balls of naphthaline from falling through. During the suction stroke the liquefied naphthaline is drawn through a spraying nozzle A_4, situated immediately in front of the inlet valve, the communication between the float chamber and the jet being nominally closed by a ball valve, which must be lifted off its seat by the suction before the liquefied naphthaline can pass to the jet. The degree of pulverisation can be adjusted by screwing the spraying nozzle nearer to or farther away from the inlet valve B_1, which opens into the compression chamber B. The amount of sprayed naphthaline fed into the cylinder is permanently adjusted by the needle valve, the position of which is controlled by the milled nut shown.

The naphthaline liquefies in the exhaust-jacketed float chamber at a temperature of 79° C., and it is interesting to find that the cost of running with this material is stated to be only a quarter of what it is with ordinary petrol on a similar engine.

The great economy in cost of fuel effected by the utilisation of naphthaline in this

way cannot fail to confer a high degree of interest upon the arrangement adopted by Messrs. Chenier and Lion.

The most interesting feature is the apparatus for converting the naphthaline into a liquid.

THE RADIATOR

The cooler is not perhaps an essential of every car, but it is generally used to expose the jacket water to the cooling effect of the air. This example will illustrate the class.

The illustration (Fig. 27) shows the Hutton radiator, and the manner in which it is put together is rendered particularly clear. Each alternate row of zigzag tubes is arranged so that the tubes cross one another instead of lying parallel throughout their length, and thus practically the whole of the air which is drawn through it by the fan, has to pass over a considerable area of tube surface. The tubes themselves form the chief mechanical support between the upper and lower plates, into which they are expanded, but light side plates are also bolted between them, and these add considerably to the general finish of this useful radiator. The filler on the top is of very large size, and contains a filter. The water is as usual drawn out at the bottom by the pump, and is led back again from the cylinder jackets to the upper chamber. These chambers, being made in two pieces, can be taken apart at any time, either for cleaning purposes or to insert a new tube, and since the entire cooler is made of aluminium it is extremely light.

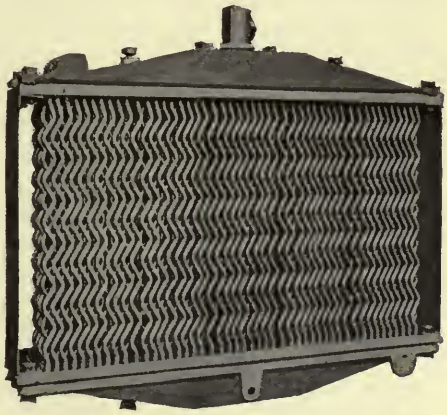


Fig. 27.—Hutton Radiator.

The whole object in the design of the water cooler is to provide as large a surface as possible to the air. And this is best done by thin plain tubes of copper or aluminium. Gills on tubes are worse than useless. Unless the tubes are vertical and wide apart, the gills have little or no effect.

THE NEW IGNITER

The next appendage to the petrol prime mover is the igniter, and electric is the only system seemingly which meets the requirements. We have already described the common systems. Recently, however, a system of some novelty has been introduced by Sir A. J. Lodge in Patent No. 2163, 1903, who proposes to use a condenser discharge of an oscillating character for ignition. This invention relates to electric ignition for use in internal-combustion engines, and has for object to render the effectiveness of the spark practically independent of the insulation of the points between which it is caused to occur. Fig. 28 shows an ordinary induction coil having primary windings *a* and secondary windings *b*. In the primary circuit is a battery *c*, a switch *d*, a trembler c^1, and a mechanical wipe contact *e* suitably geared to the shaft *f* of the motor. Each of the secondary terminals *k*, *l* is connected to one element of separate condensers *m*, *n*, the other elements

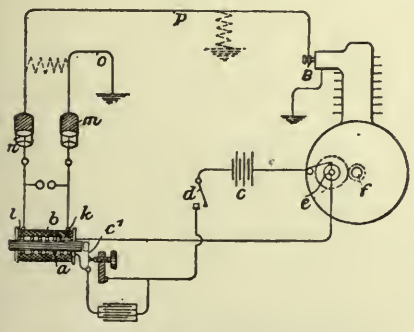


Fig. 28.—Lodge's Ignition System.

of which are connected by leads *o*, *p* to earth and to the sparking plug B. The secondary terminals are also connected direct to the sparking point A. The ordinary Leyden jar discharge occurs at A, and every time such spark occurs the contents of the condensers are liberated, and give rise to the required spark in the ignition chamber. This system is said to give remarkably reliable results. It certainly has the merit of novelty.

Another recent improvement in magneto-ignition comes from Germany by A. Schoeller, Frankfort, and is shown in Fig. 29. The invention consists in so constructing magneto-electric apparatus that the revolving inductor armature is stopped for a certain time during a revolution, and is then caused to make good the extent to which it has lagged behind by passing through that distance at an increased speed, and thereby producing a stronger current in the electric circuit. This action is done away with by hand or automatically as soon as the internal-combustion engine, and consequently also the armature, has attained its normal speed. M is a magneto-inductor, on the armature spindle W of which is loosely mounted a chain-wheel A driven by the engine. D is a cam disc combined with the wheel A, and so shaped that an arm K pressed against its periphery by a spring B is caused to drop at one part of its rotation and engage a lever N on the spindle W. This lever is spring controlled, and the spring F_1 is stressed when the lever and, consequently, the armature are so held. The arm K is lifted by the continued rotation of the cam, and the spring causes the armature to be rapidly thrown forward until the lever has resumed its original position relatively to the wheel A, in which position it bears against a stop S.

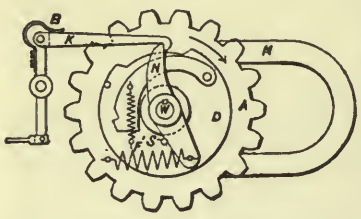


FIG. 29.—Improved Magneto-Igniter.

THE CLUTCH

The petrol, like most other internal combustion engines, is not reversible, and is naturally a constant speed motor. It is therefore necessary to combine with it a clutch whereby the engine may be readily disconnected or connected to the driving axle of the car, and also with some mechanical gearing whereby the speed of the car may be varied while the engine runs on, and the direction of motion of the car may be reversed without reversing the engine. This necessity for clutches and gearing to transmit the power of the engine to the car wheels is the chief drawback to the internal combustion engine in locomotive work of all kinds, and all the mechanical skill and ingenuity hitherto spent upon this element to bring it into practical perfection has had only qualified success. Gearing in all mechanisms is a necessary evil, if it must be used. And the engineer of experience always makes every endeavour to do without gearing of any kind wherever it is at all possible. It is necessary in all petrol cars. The Crossley clutch and gear may be taken as examples. The main clutch, which is shown in Figs. 30 and 31, fits inside the fly-wheel N on the rear end of the crank shaft D. The projecting end of the shaft carries the casting N_1, which is free to revolve upon it, and is fitted with a long brass bush for this purpose. The shape of this casting is best seen in Fig. 31, and in the elevation it will be noticed that at its upper end it carries the brake shoes N_5 pivoted to it. At its lower end a socket N_2 is secured to it by the bolt N_3, and the socket has left- and right-hand screw threads formed inside it. Before the bolt N_3 is inserted, the socket N_2 can be turned round about its axis so as to draw the lower ends of the two levers N_4 (and therefore the lower ends of the shoes N_5) nearer together or to press them farther apart, it being pivotally connected with those levers as seen in the elevation. The levers N_4 are connected together at their upper ends N_6 (Fig. 30) by a strong helical spring N_6 (Fig. 34), and they are connected by links with

the lower ends of the shoes N_5. Centrally, these levers N_6 carry small rollers N_7, which are normally clear of the casting N_7. A sliding wedge N_8, which rides on a feather key on the sleeve N_1, is so arranged, however, that its sloping surfaces can be brought into contact with the rollers N_7, and so force the levers N_4 outwards against the action of the spring. The effect of this action is to bring the lower ends of the shoes N_5 nearer together, and thus withdraw their cast-iron friction faces away from the inner face of the fly-wheel N. The wedge piece N_8 is formed with a groove for the split collar N_5 to ride in, and this collar is engaged by the forked lever fixed to the rocking shaft P_2 on the chassis. It will be seen that the spring N_6, which is adjustable, tends to force the brake shoes outward, that the contact surfaces of the shoes only extend over about one-half of the complete circle, and that the end-thrust imposed by the wedges N_8 is taken by a ball-thrust bearing fitted between the fly-wheel and the casting N_1. The bearing inside the casting is lubricated

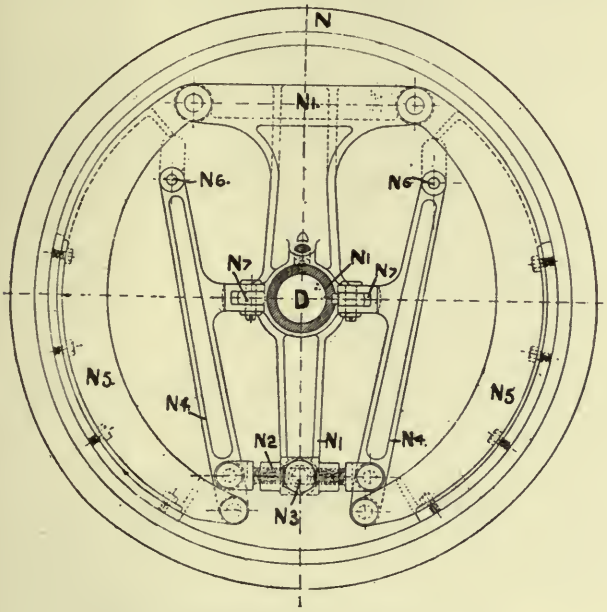


FIG. 30.—Elevation of Crossley Clutch.

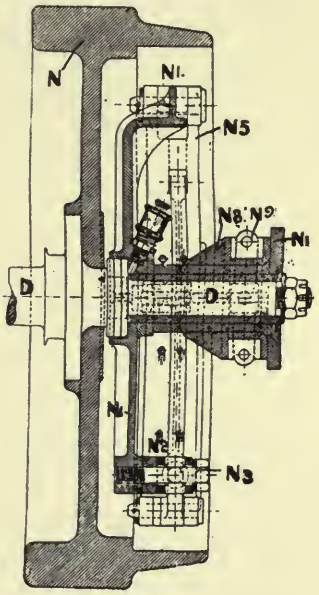


FIG. 31.—Section of Crossley Clutch.

from the grease-cup seen in Fig. 31, and the collar N_8 from another grease-cup, which is visible in Fig. 34.

The clutch pedal is mounted upon a shaft, which passes across the chassis and is rigidly fixed to a short arm projecting forward from it. The fork engaging with the collar N_9 by pins is mounted upon the transverse shaft, and it carries an eccentrically mounted steel roller, with which the end of the lever arm engages. When the pedal is depressed the arm acts upon the roller and causes the clutch fork to turn about its axis, a very powerful leverage being in this way obtained. When the pedal is fully depressed the roller rests against the end of the lever, and therefore can exert but little force on the pedal against the driver's foot, very little exertion consequently being needed for holding the clutch out of engagement.

THE CHANGE-SPEED GEAR

The Crossley change-speed gear is illustrated in Figs. 32 and 33. The first-motion shaft R has a square section inside the gear box Q, and its forward end takes a bearing

inside the sleeve of which the bevel wheel T and the jaws clutch member T_1 form parts. The three spur-wheels R_2, R_3, and R_4 are mounted upon a sleeve, which is free to

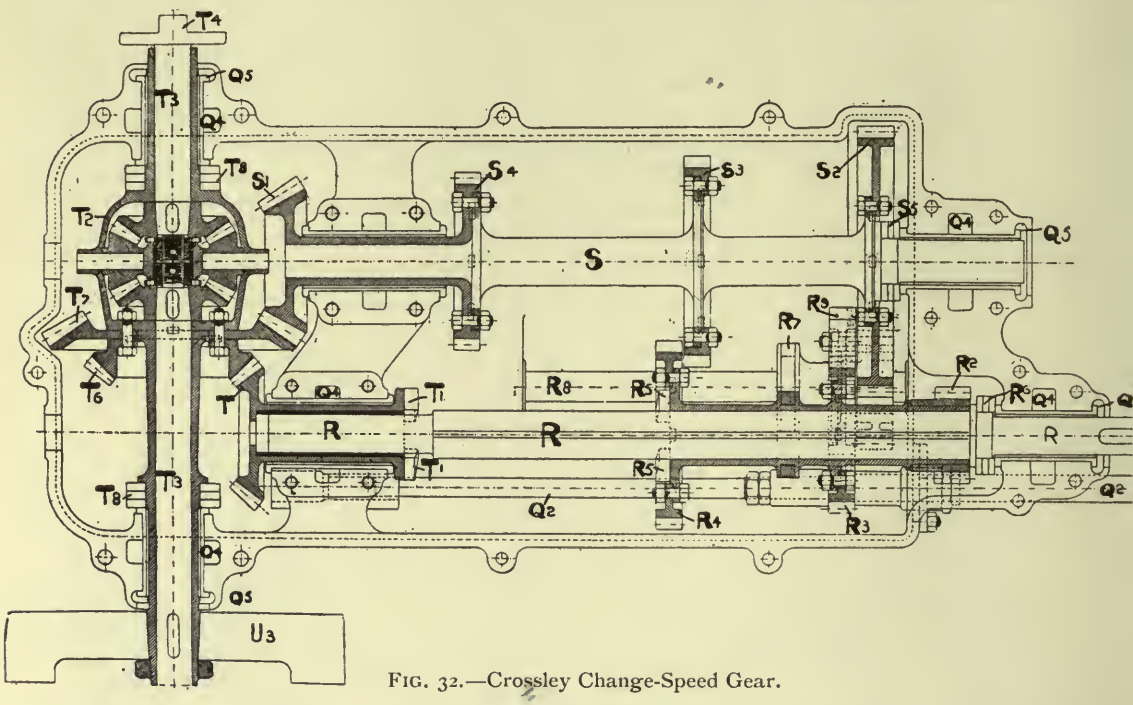


FIG. 32.—Crossley Change-Speed Gear.

slide upon the square portion of the shaft R, and the front end of the sleeve carries jaw-clutch members R_5, which engage with the similar jaw-clutch member T_1 when the sleeve is moved to its farthermost position rearwardly. The second-motion shaft S carries three spur-wheels S_2, S_3, and S_4, which correspond with the wheels R_2, R_3, and R_4, to give the first, second, and third forward speeds respectively. This shaft terminates at its rear end in the bevel wheel S_1, which meshes with the wheel T_7 on the differential gear, whilst the direct through bevel T meshes with the other bevel wheel T_6 alongside it. Except on the top gear the power is transmitted from the first-motion shaft R to the second-motion shaft S, and from it through the bevels S_1 and T_7 to the shell T_2 of the differential. On the top gear, however, the jaw-clutch members R_5 engage with those of T_1, and the power is then transmitted direct through the bevels T and T_6 to the differential. The "reverse" is obtained by a pair of wheels R_9, which are mounted together on a sleeve that is free to slide upon a shaft R_8 in the base of the gear box. This sleeve is at all times con-

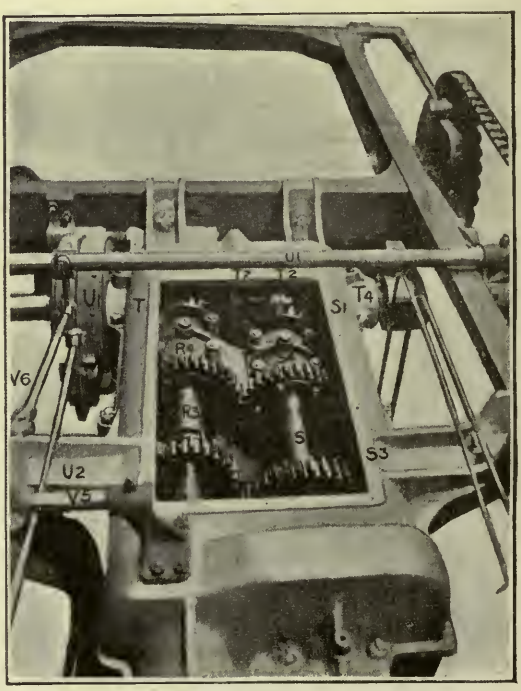


FIG. 33.—Crossley Change-Speed Gear.

nected with the sleeve on the first-motion shaft by the fork casting R_7, and both in turn engage with the sliding rod Q_2, which is connected with a hand lever. One of the intermediate wheels R_9 is at all times in mesh with the spur-wheel R_8, and the other comes into gear with the low-speed wheel S_2 on the shaft S. The thrust of the bevel T is taken by the ball-bearing R_8, and that of the bevel S_1 by the ball-bearing S_5. The outer member of the differential gear is also arranged between ball-thrust bearings T_8, which take the end strains imposed on it by the bevels T_6 and T_7. All six bearings are ring lubricated, and have small oil troughs Q_4 formed in them for this purpose. Each of the four outside bearings, too, have grooves Q_5 arranged so as to catch any oil which may find its way through them. As we have already said, flexible couplings T_4 are introduced into each half T_3 of the differential counter shaft, and ball-bearings T_5 are fitted at either end close up to the sprocket-wheels driving the side chains. The gear box is provided with an unusually large cover, which enables a thorough inspection to be made at any time.

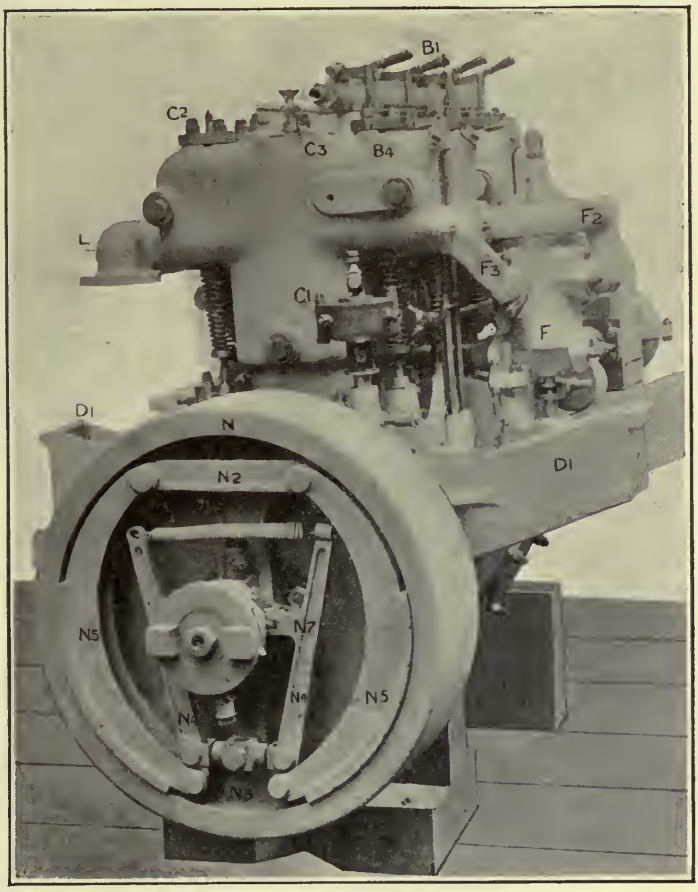


FIG. 34.—View of Crossley Engine showing Clutch.

The four forward gears on the standard car represent normal speeds of about 11, 22, 35, and 48 miles per hour respectively, when 20-tooth sprockets are fitted on the counter shaft.

Fig. 33 represents the Crossley gear in its place on the chassis, and Fig. 34 shows the clutch on the fly-wheel in its place on the engine.

VALVES AND VALVE GEARING

The parts just described, the carburetter, the clutch, and the speed and reversing gearing, governor, and igniters, are all separate parts outside of the prime mover itself, but still essential to its performance of the work to be done. Engine makers, like the earlier electric motor makers, make a great mistake in not paying sufficient attention to these essential adjuncts to the engine. Many engines are sold without them, with the idea that the purchaser can find them from special manufacturers. It would be better an engine maker does not make gearing, igniters, carburetters, etc. etc., that he should at least make a selection of these best suited for his engine, and supply them with it wherever required to do so. The parts of the prime mover now to be described are

integral parts of the engine, and no engine is considered complete without them. It will be desirable for those who have not made a study of the little petrol prime

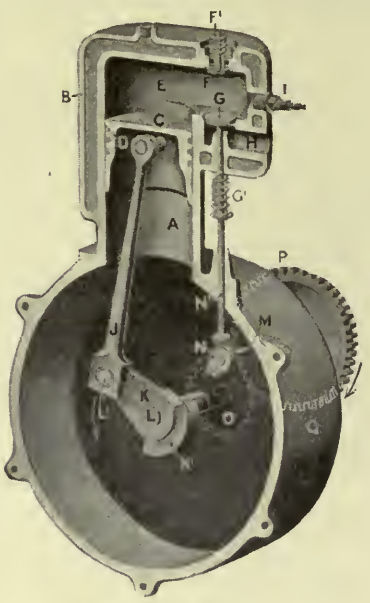


FIG. 35.—Working.

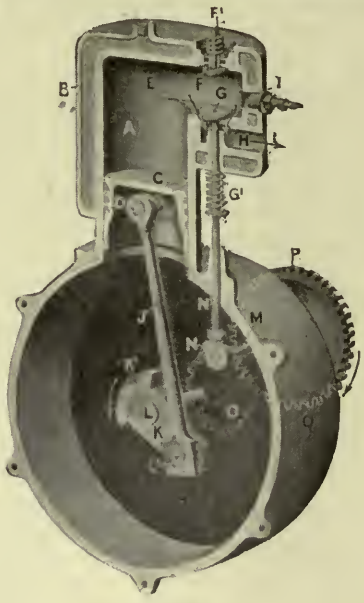


FIG. 36.—Exhaust.

mover to go over the several parts and their functions *seriatim*, so as to fix their names and operations in mind, and four little figures given in the *Autocar* some time ago will serve admirably for the purpose.

Referring to Figs. 35, 36, 37, and 38:—

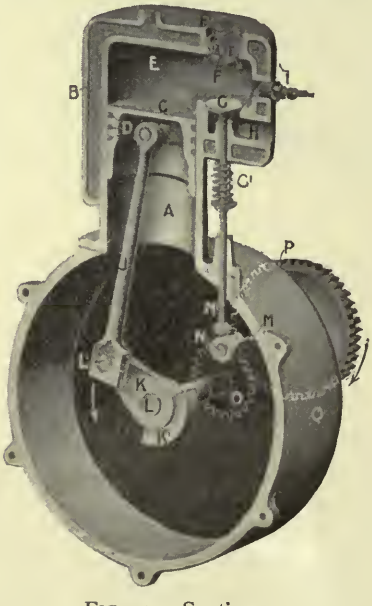


FIG. 37.—Suction.

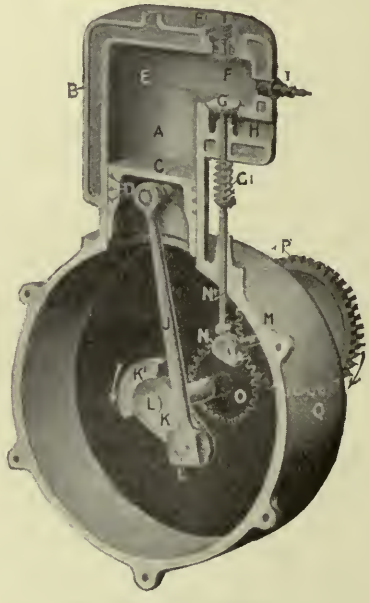


FIG. 38.—Compression.

A is the cylinder, usually of cast iron, and jacketed by an outside casing to hold water.

B is the water-jacket casing surrounding the cylinder, in order to maintain a

temperature considerably below the boiling-point of water. The heat of the explosions in the cylinder would very soon make the cylinder pistons and valves red hot and unworkable. And if the heat of the cylinder piston and valves exceeds a certain value or temperature, the incoming mixture of fuel and air would catch fire and prematurely explode. For these reasons water cooling is necessary in all internal combustion engines.

C is the piston, also of cast iron, and fitted with spring rings to make it gas-tight, so that while it slides easily in the cylinder yet no gas can escape past its rings. The piston should be of as small a weight as possible, consistent with strength required.

I is the wrist pin to which the small end of the connecting rod J is hinged. This pin is in rather an awkward position for efficient lubrication or examination, and is therefore often troublesome, and in small motors is a weak spot.

K is the crank, with a balance weight K^1, which converts the reciprocating motion of the piston into rotary motion.

L is the end of the crank shaft, and L^1 the crank pin.

This engine, like most autocar engines, works on a 4-stroke cycle, that is, gets an explosion once in every two revolutions ; hence the valves and ignition must be operated once for two revolutions. It is therefore necessary to provide a mechanical reduction gearing, whereby a second shaft shall be driven from the crank shaft at half the engine speed; hence we have wheels and a shaft.

O is the toothed wheel on the crank shaft gearing into P, a toothed wheel on the other shaft.

M, called the cam shaft, for it carries cams to operate the valves and ignition.

N is the cam shown for working the exhaust valve in this case.

The wheel P has twice the number of teeth that are on O, hence the cam shaft rotates at half the speed of the engine.

Q is the crank case, usually of aluminium.

N^1 is the valve rod.

G is the exhaust valve, and G^1 the valve spring which closes it.

F is the inlet valve, with a closing spring F^1. This inlet valve is attached by a pipe to the carburetter, and the exhaust valve G opens into an outlet exhaust pipe at H.

E is a space at the cylinder end in which the mixture of fuel and air is compressed and fired.

I is the sparking plug for high pressure spark ignition.

On the outer end of the cam shaft there is usually an electrical contact maker and breaker to turn on and off the electric current at the proper moment for ignition. It is not shown in the Figures. It may be illustrated by Fig. 39, from the E.I.C. of Birmingham, who make a speciality of autocar ignition apparatus. The little disc with two screws and a segment of brass on its periphery is fixed on the end of the cam shaft. On this disc presses a contact lever or two. This lever is insulated electrically, and makes electrical contact with the segment on the disc as it comes round at the right moment for ignition. The box carrying the contact levers is carried on pins in a slot, so that the box, and with it the levers, can be rotated to some extent forward or backward around the cam shaft in order to adjust the contact for ignition at the best point.

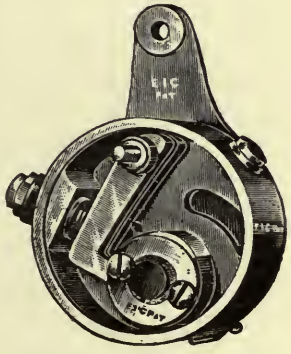


FIG. 39.—Contact Maker.

Having described the various component parts of a simple motor, we may now consider their functions in the running of the engine. Referring to Fig. 35, the mixture in E has just been exploded by the spark at I, and the high pressure on the gases exploding is pressing down on the piston with a pressure which at the instant when the piston is in the position shown may be 100 lbs. per square inch of the piston area. If the piston is 5.5 inches diameter, its area will be over

23 square inches; so that the total pressure will be in this instance 23 × 100 lbs., somewhat over one ton. Now it will be realised to what a strain the little wrist pin D, the connecting rod J, the crank pin L^1 and crank K, are subjected every time the engine puffs.

Immediately after the engine gets the explosion, the pressure falls gradually as the piston descends, so that although the pressure may be as high as 200 lbs. per square inch at the instant of explosion, it falls to a few lbs. per square inch at the end of the down-stroke. And so if we take all the pressures during the stroke from beginning to end, we will find that the mean or average pressure may be only 50 lbs. more or less. This is the pressure we calculate upon to do the work, and the horse-power is thus calculated. We will suppose the engine is making 600 revolutions per minute, and the piston stroke is 6 inches. It is evident the piston must travel 600 feet per minute, for it makes one foot of travel every revolution. But the piston is subjected to the mean pressure during only one-fourth of the time, that is, during half a revolution every second stroke; hence the travel of the piston while under pressure is only $\frac{600}{4} = 150$ feet per minute.

Now, if we multiply the feet per minute during which the pressure operates, by the total pressure, we get the foot-lbs. of work done, and this divided by 33,000 will give us the horse-power; thus if F = feet per minute during pressure, and P = pressure, and H.P. = horse-power, then $\text{H.P.} = \frac{F \times P}{33{,}000}$; and if the power is wanted in watts or kilowatts instead of horse-power, $W = \frac{F \times P}{44.2} = \text{watts}$, and $KW = \frac{F \times P}{44.2 \times 1000}$.

In the case taken we have area of piston, 23 square inches; mean pressure per square inch, 50 lbs.; hence total pressure = 50 × 23 = P = 1150 lbs. And F the feet travelled under pressure = 150 feet per minute; hence $\frac{1150 \times 150}{33000} = 5.2$ horse-power, and $\frac{1150 \times 150}{44.2 \times 1000} = 3.9$ kilowatts.

It will now be clear whence the power cometh and where the strains are thrown. Now, the piston having arrived at the end of the down-stroke under pressure begins to come up again, as seen in Fig. 36. The gases in the cylinders having done their work, must be let out. The cam N now comes into play and opens the outlet exhaust valve G, and the piston coming up pushes out the spent gases; this is called the exhaust stroke. The first stroke is called the working stroke. The piston arriving at the up end again, the exhaust valve is closed, and the piston begins to descend again, as in Fig. 37, being pulled down by the rotating crank kept going by the fly-wheel inertiæ. The piston going down leaves a partial vacuum behind it, and the inlet valve being closed only by a weak spring in this case, is opened by the suction, and a fresh charge of air and fuel is drawn in through the carburetter, and the cylinder is filled with an explosive mixture again. The piston now begins to rise again as in Fig. 38. Being pushed up by the crank under the impetus of the fly-wheel on the crank shaft, it compresses the mixture, closing the inlet valve until the mixture fills the combustion space E again, and the piston coming to the top is ready for another explosion. These four operations together are called a cycle, and this four cycle is repeated over and over again.

It will now be clear how the 4-cycle engine works, and also the essential features of a simple engine.

The opening of a valve by simple suction is not positively certain in action,—it may stick, the spring may break, it may open too late or too much; hence in all good engines this valve is made to be opened by the cam shaft with another cam, and in some, one cam does both offices, working both exhaust and inlet valves. From Mr. R. E. Phillips' (M.I.M.E.) paper on "Valves and Gearing," contributed to the Automobile Club, we can gather the essential features of some examples of mechanically operated inlet valves.

We shall have occasion to refer to other valves on the engines to be described as examples on autocars,—and in this connection it is to be remembered that it is methods and systems we are studying, not actual details of construction in these cars. We are concerned with the prime mover and its details only at present.

Fig. 40 shows the manner of application of valves to the Rochet-Schneider engine. Cap C screws into head of cylinder, keeping valve seating B in position, C being bored to receive plunger D working freely therein, and contracting washer a^1 on stem a of valve A, against which one end of spring E retaining valve on seat bears. The end of plunger is recessed to receive end of stem a of valve, and is slotted to clear cotter locating washer a^1 on the valve stem, so that plunger engages washer only. On top of cylinder is pivoted lever F engaging top of plunger through adjustable set screw. A bell crank G is pivoted on crank case, its vertical arm engaging exhaust cam at 90° from point at which motion for operating exhaust valve is taken. The arm G is connected to lever F by rod H as shown. The cam therefore operates to depress the plunger D and the spring E, thus removing its pressure from the valve A. As the exhaust cam is arranged to give exhaust valve a lead the pressure of the spring E is

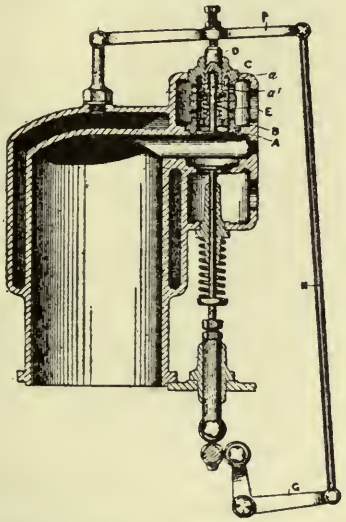


FIG. 40.—Rochet-Schneider Valves.

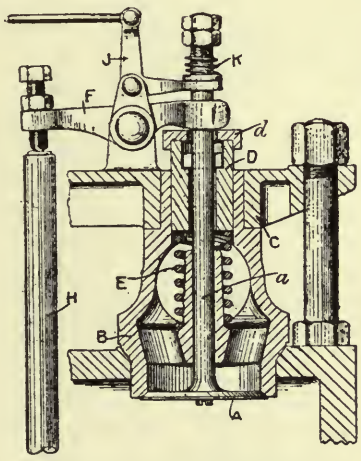


FIG. 41.—Variable Inlet Valve.

removed from the induction valve before the end of the exhaust stroke, so that it is only retained on its seating by the pressure of the exhaust gases in the cylinder. It therefore opens immediately the said pressure falls to that of induction pipe, and it falls by gravity. To force the valve down in case of sticking, the recess in plunger D is made of such depth that the plunger contacts the top of the stem immediately after the time valve should open normally in case gravity has not had its effect.

Index to Fig. 40:—

A, Valve.
a, Stem of valve.
a^1, Washer on stem of valve.
B, Seating for valve.
C, Cap locking valve seating in position.
D, Plunger.
E, Spring retaining valve on its seating.
F, Rocking lever operating plunger.
G, Bell crank lever operated by exhaust cam.
H, Rod connecting bell crank lever G with rocking lever F.

In Fig. 41 the valve is designed for application to the engine of a well-known car, and the modification in the above construction can easily be grasped by means of the Figure and the lettered reference. The bell crank lever J provides a simple means of

throttling by varying the lift of the valve. The small spring K acts as a cushion to break the fall of the valve when opening.

Index to Fig. 41 :—

A, Valve.
a, Valve stem.
B, Valve seating.
C, Stirrup retaining seating of valve in position.
D, Plunger working in upper part of seating.
E, Spring retaining valve on its seating.
F, Rocking lever engaging plunger.
H, Rod operating rocking lever F.
J, Device for varying lift of valve.
K, Spring acting as cushion to break fall of valve.

Fig. 42 is a modification in which the controlling spring E is arranged outside the valve box, and its general action can be quite easily gathered from the diagram.

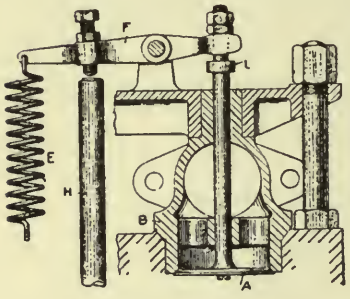


FIG. 42.—Inlet Valve.

A, Valve.
B, Seating for valve.
E, Spring retaining valve on its seating.
F, Rocking lever engaging stem of valve
H, Rod operating rocking lever.
L, Collar on stem of valve for rock lever to engage with in case valve has "stuck up" on its seating.

When it is desired that the induction valve shall open upwards, as in Fig. 43, a spring M is employed to lift the valve, the strength of the spring being slightly more than equal to the weight of the valve. In engines of one or more cylinders the motion for operating the induction springs can be taken direct from the lifters of the exhaust valves. The efficient action of the Phillips' valve is not affected by loss or compression, but rather compensates for it. It cannot open incorrectly owing to its automatic action being dependent on conditions that govern correct timing. It automatically adjusts itself to its work, and wear and tear do not affect it, and lastly, in engines of four or more cylinders a number of working parts can be dispensed with. Users and makers would appreciate these advantages. Grinding in is the only attention required of the former, and for the latter a considerable saving of time is effected in turning up an engine with multiple cylinders, while the reduction of parts means reduction in cost. Many attempts have been made to obtain the operation of induction valves from the exhaust cams, but none as yet can be considered practical, as none provided for independent adjustment of the timing of the two valves. It is argued that such adjustment can be obtained by adjusting the strikers or lifters of one valve to operate before or behind the other valve, but it is a fallacy, owing to the necessity of dealing with four adjustments, two at each end. By eliminating one adjustment, as possible with the auto-mechanical valve, by reason of the fact that the time at which the spring is released from the valve to render it free to open automatically is immaterial within certain limits, the thing becomes feasible. With the exhaust valve properly adjusted it is necessary only to adjust the closing time of

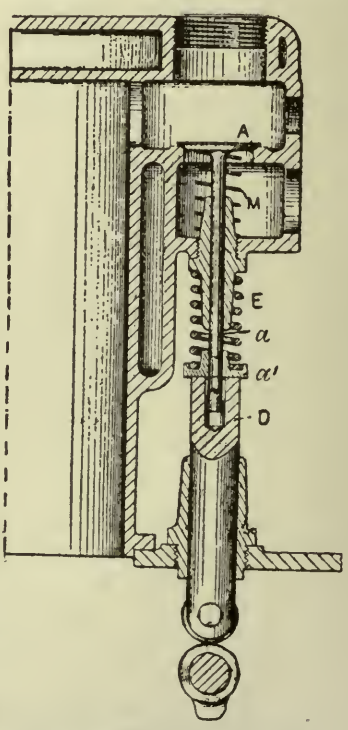


FIG. 43.—Inlet Valve opening upwards.

the induction valve, as the time of opening calls for no adjustment. The relative efficiency of any two types of valves cannot be compared even with the same engine unless the carburetter is tuned up to suit the altered conditions. A carburetter arranged to give perfect mixture with a sharp abrupt action, as with an atmospheric valve, would give an inferior mixture with more regular or less abrupt suction such as provoked by M.O. valves. Neglect of this fact by makers has probably been at the bottom of failure to get better results with M.O. than with atmospheric valves. Uniform carburation can be obtained by opening induction valves before any vacuum was formed in the cylinder and closing it mechanically at or slightly after dead centre, as the inertia of the inflowing charge makes up for any difference between speed of valve and piston as piston approached end of stroke. The best designed valve will be inefficient if ports and pipes are not properly proportioned.

Index to Fig. 43 :—

A, Valve.
a, Stem of valve.
a^1, Washer on stem of valve.
D, Plunger formed in one with the lifter or striker operated by cam.
E, Spring retaining valve on its seating.
M, Spring operating to balance valve, and assisting it in opening.

The details described are common to all 4-cycle engines working with petrol. We have, however, 2-cycle engines, which, although not fashionable at present, have something in their favour to be said. They have been given a bad name owing to enthusiasts forcing them into use before they had been properly designed. We have already fully described properly designed 2-cycle engines for stationary and marine purposes in Volume II. In the Glover engine we have a type perfectly well able to hold its own against 4-cycle engines.

A 4-cylinder 2-cycle engine would give a fine even turning movement without much of a fly-wheel effect. An exhaust fan or piston pumps would be no trouble to deal with the suction on the exhaust.

In order to facilitate reference to this type of engine, Fig. 44 is here reproduced from page 158 of Volume II. It will be seen that this engine differs from the four stroke but little. The piston is prolonged, and has an enlarged head P acting as an exhaust pump to draw the exhaust gases from the cylinder. It has an inlet valve, and in practice these are operated by a cam shaft mechanically at the proper moment. The vessel C is an exhaust cooler or condenser.

The action of this engine is as follows :—Beginning at the top of the

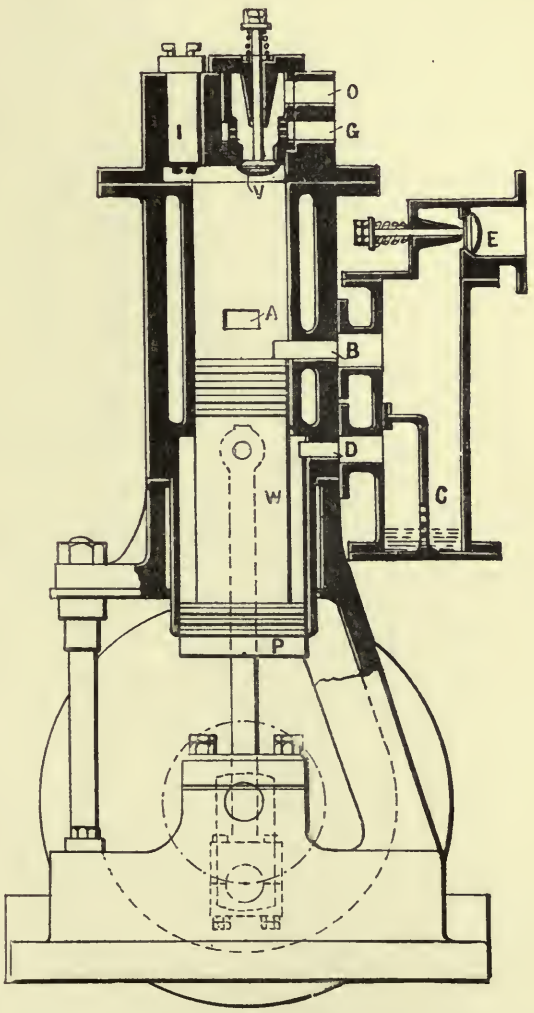


Fig. 44.—Two-Stroke Suction Engine, with Cooler.

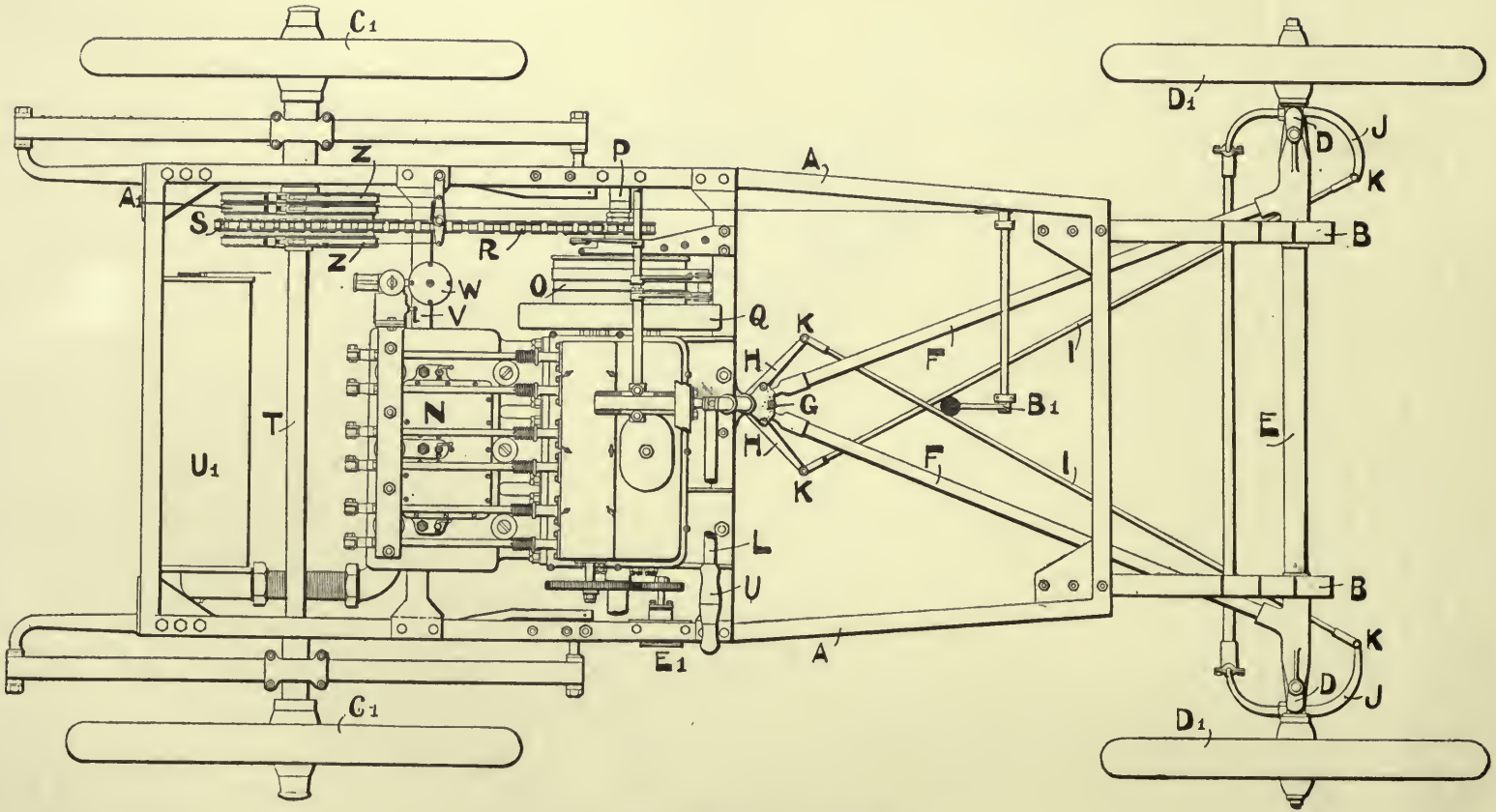


FIG. 45.—Plan of Duryea Chassis.

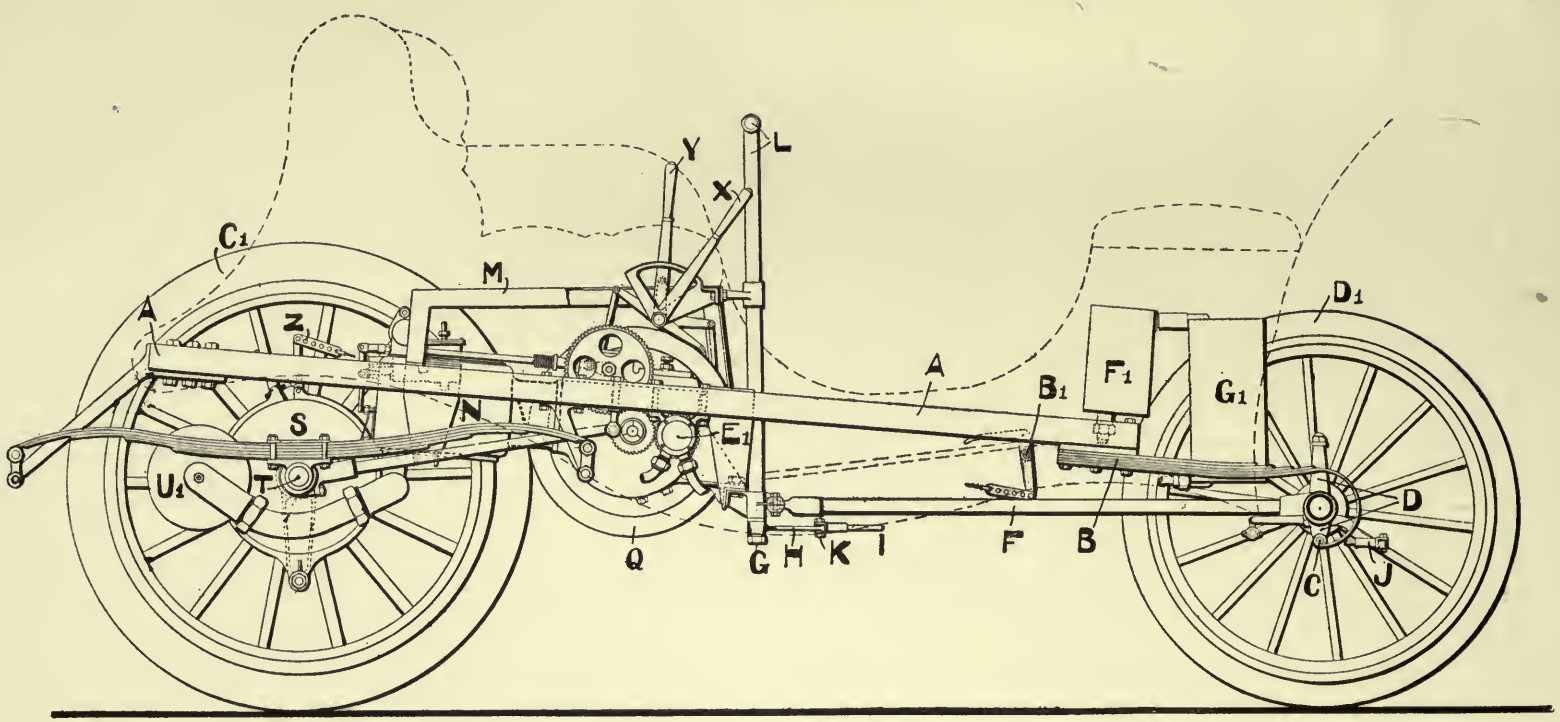


FIG. 46.—Elevation of Duryea Chassis.

stroke, a spark I ignites the mixture which has been compressed by the previous up-stroke, and the pistons descend driving the crank, the larger piston making a partial vacuum in W cylinder. When the working piston uncovers the port A the pressure is reduced to atmospheric, then port B is uncovered, placing the cylinders in communication through C and D; the remaining exhaust gas is sucked out by the partial vacuum in W, and fresh mixture of fuel and air is drawn in through O, G, and V. The valve being opened mechanically, the piston then begins to rise, closes B, and the large piston forces out the contents of W through condenser C and out at exhaust valve E. A is then closed, and the mixture compressed to the end of the up-stroke, when it is again ignited. This cycle is repeated again and again.

It has been suggested that some of the charge escapes with the exhaust, but a large experience of 2-stroke engines does not prove that this is the case.

We can now proceed to examine a few typical autocars in order to ascertain the present state of the art and science of their design and construction, taking first a somewhat novel design originating in America. In that country they are styled power carriages.

DURYEA POWER CARRIAGES

Simplicity of design and fewness of parts have been kept to the front in the arrangement of this chassis. The illustrations Figs. 45 and 46 will show the general arrangement, which differs in almost every detail from the usual type. The frame A is of channel steel, ash-lined, tapering slightly forward, where it is supported upon two semi-scroll springs BB hinged to brackets C carried on the under side of the head lugs DD, which are built up on a weldless steel tube axle E, the head lugs being sloped so as to bring the steering line almost coincident with the wheel centre, and so obtain irreversible steering without the use of worm gearing. Instead of it being left to the springs to push the axil forward, these have only vertical action to deal with, the axle being held up by two stout tubular supports FF universally jointed at the base of the steering post G. This latter is vertical, and is furnished with two arms HH at its base, from which crossed rods II are carried to the steering arms JJ, this arrangement avoiding lost motion, and putting the whole of the steering connections in tension, and relieving it of all compressional strains. The steering connections K are adjustable for wear. The steering is done by a powerful horizontal lever L, which is not only adjustable to suit the convenience of the individual driver, but may be turned up to allow of easy ingress to the seat, or even turned right over and the steering done from the other side. Immediately at the back of the steering post is the seat frame M—a light construction of angle steel, and beneath this the engine N.

There is no counter shaft, and the usual change-speed gearing is absent, a small "power drum," or epicyclic gear O being carried on one end of the crank shaft and supported by a bearing P on the frame. Ordinarily, this gear is locked solid with, and effectively forms a part of, the fly-wheel Q. It carries a sprocket and a single chain—a roller by Hans Renold, which is tested to a breaking strain of about five tons. This makes a really direct drive to the differential S (Figs. 45 and 46) on the back axle T, without the use of bevel wheels or other power-absorbing devices, as both shafts are parallel. The action of the gear and the speed of the car are controlled as follows:—A twisting grip on the steering handle actuates a throttle lever V in connection with an automatic float feed carburetter W (Fig. 45), and so controls the speed of the engine within a very wide range. A hand lever X in the middle of the front of the seat slips the clutch or locks it, and, moved in the contrary direction, frees the clutch and brings the epicyclic gear into action, with a gear reduction of 66 per cent., with which hills of great steepness may be climbed. A second handle Y, by the side of the

first, when moved one way reverses the motion of the gear, with a 50 per cent. reduction in speed, and, moved the other way, applies a pair of powerful compensated metal to metal grip brakes Z in direct connection with each wheel. In the matter of brakes, it may here be said that the car is exceptionally well fitted. A single grip brake A_1 similar to the other two, and worked by a foot lever B_1, acts upon and through the differential, and the application of neither of these puts the engine out of gear, which by throttling back is regularly used for braking purposes. The differential is enclosed in an oil-tight and dust-proof case. The driving wheels C_1 are 36 inches and the steering wheels D_1 30 inches in diameter, with wood spokes and tyres to order. The gear-driven pump is shown at E_1, the water tank at F_1, and the radiators at G_1, these latter being invisible from the side of the car. The chassis shown illustrates that used in the 12 horse-power Phaeton type. That of the 15 horse-power series is longer, but in general details the same.

The Duryea engine is of the horizontal type, and is illustrated in Fig. 47, a sectional plan, and Fig. 48, a sectional elevation. Set with the cranks forward and slightly inclined from the horizontal, the three cylinders A with cylinder heads and water jacket BB, are cast in one piece without joints of any kind,—the water jackets have aluminium covers top and bottom, bolted on,—and are bolted down to a strong aluminium crank case, with removable cover secured by bolts, so that, should it be required to take out the pistons, the removal of eight nuts allows the cover, with all the valve gear of the engine undisturbed, to be bodily removed, and to be readily replaced. The valves, both inlet D and exhaust E, are mechanically operated, and all six valves, together with their operating mechanism, are alike and interchangeable. Instead of having valve chambers at the sides of the cylinders, all valves are in the engine heads, the inlet valves opening into a single inlet pipe, which crosses the top of the engine, and the exhaust valves opening into a large single pipe, which crosses the bottom of the engine, and takes leads from each one. The valve seats—which, as will be seen, are entirely surrounded by water—are detachable with the valves, the removal of one nut and the bolt of the tappet rod allowing of the seat being withdrawn with its valve and spring in position. The valves are operated by valve-actuating rods L and tappet rods L_1, and are closed by springs F, all six rods being worked from one cam shaft K, worked by the two-to-one gear wheel J. The removal of an inspection cover exposes all six to view at the same time. The bore and stroke are alike, namely, $4\frac{1}{2}$ inches, the 12 horse-power engine giving its power at 600 revolutions and the 15 horse-power at 750. The cylinders and pistons are both considerably longer than usual, with the object of preventing rocking, and minimising cross-binding, and a unique feature is found in the setting of the crank shaft H in advance of the cylinder axis, the difference in the lines of the two axes being shown by the lines MM and NN in Fig. 48, the effect of this being to reduce the angularity of the thrust, getting an almost direct thrust on the driving stroke, lessening the wear and cross strains on the pistons, and reducing the vibrative effect. The crank shaft is forged solid, and has the cranks set at 120°, and the connecting rods G are furnished with oil cups to feed the crank pins, the entire lubrication of the engine being done by splash from the crank chamber.

The new Duryea-Dawson magneto (not shown in illustration), worked off the half-speed shaft and carried on the crank case, is used for ignition, and after passing the current generated through a coil, it supplies it to the engine through the ordinary sparking plugs. A novel device in this instrument gives a firing spark, however slow the magneto is turned, so that there is no trouble in starting, and it also automatically governs the sparking, according to the speed of the engine, advancing or retarding as the speed rises and falls.

The Duryea transmission gear is a very efficient type of transmission operated entirely by friction clutches of large surface, which secures long life and easy operation besides doing away with the wear and constant danger of breakage involved in the use

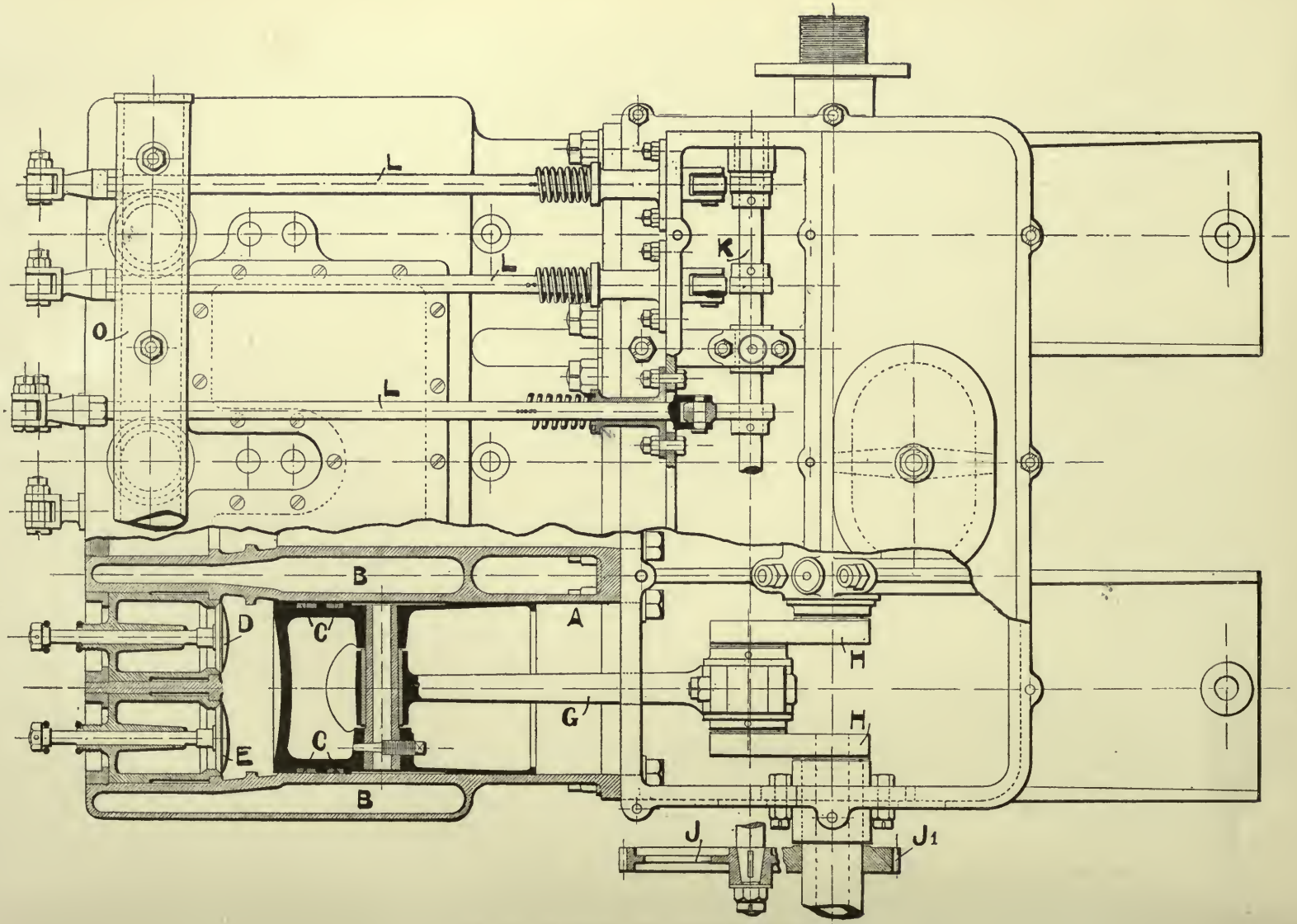


FIG. 47.—Sectional Plan of Durvea Engine.

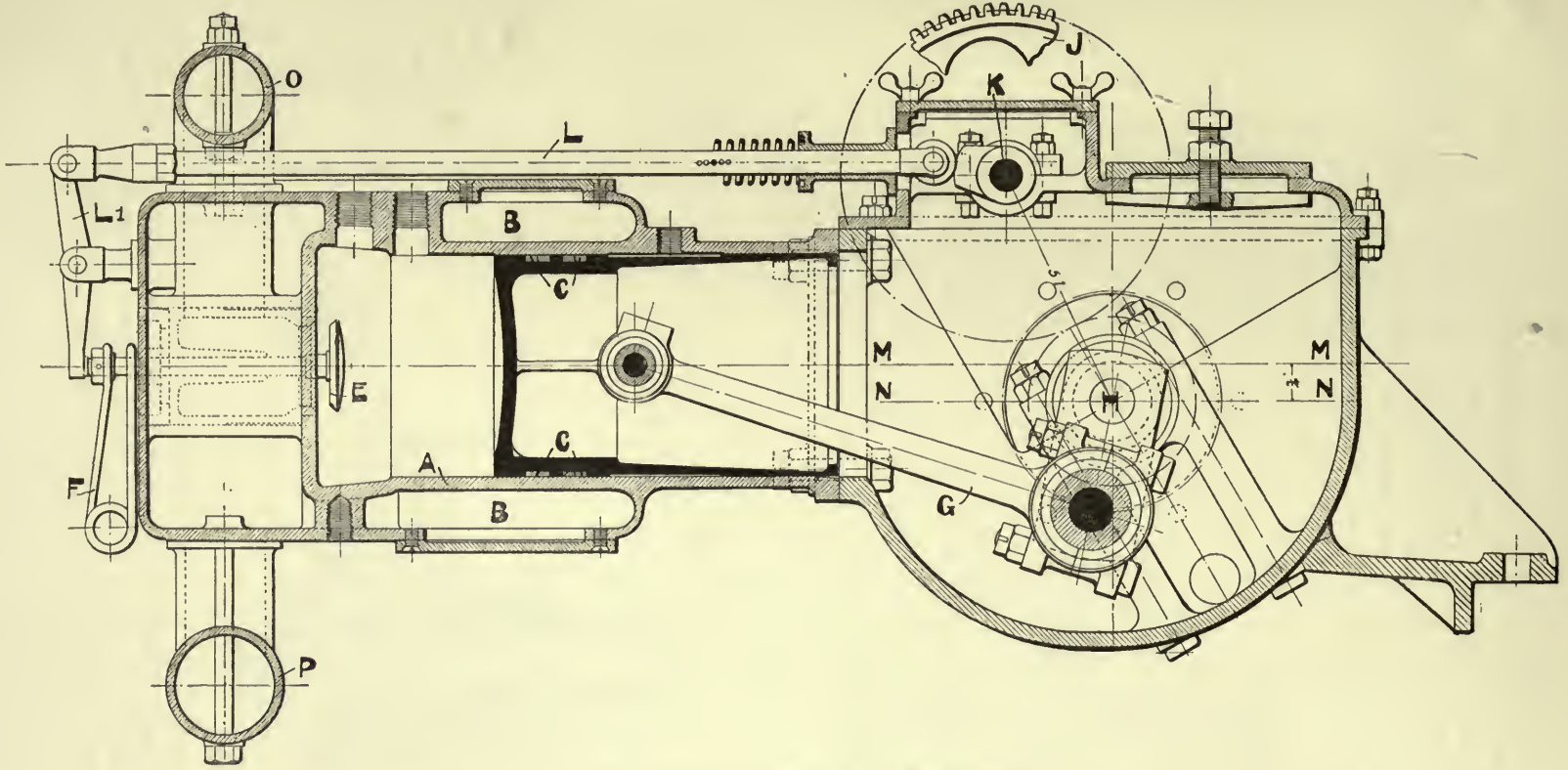


FIG. 48.—Sectional Elevation of Duryea Engine.

of shifting gears. As indicated in Figs. 49 and 50, the small gear A is secured to the motor shaft against the fly-wheel flange by screw threads. Meshing into the gear A are three planet or idle gears marked A_1, which are journaled upon studs provided on a triangular frame to receive them. This triangular frame is journaled upon an extension of the motor shaft, by which arrangement the planet gears are held concentric with the driving gear A, and both the gears and their supporting framework are further held in alignment with the various parts, to which they may be attached in making the several changes. This triangular frame is double, one part K being formed integral with the studs, and the other part attached to the studs by nuts on their projecting ends, which latter part carries the reverse ring H, while both parts of the frame form supports for the clutch pins P and their actuating levers M, of which the functions will be described later. Encircling the planed gears A_1 is an internal gear X attached to the slow-speed ring B, which is supported upon the disc E by projecting lugs; while the disc E in turn is journaled so as to remain concentric with the motor shaft, and thus support the internal gear X in concentric relation and proper alignment with the other parts. Friction bands, not shown, are attached to the framework of the vehicle and encircle the ring H and the ring B, being provided with levers by which either band may be caused to grip its corresponding ring at the will of the operator. If the reverse ring H is gripped by its band, the planet gear studs, with the attached framework, will be held stationary, and the motion of the motor will be transmitted from the gear A through the planet gears A_1 to the external ring, driving same in a reverse direction. If the slow-speed band is gripped upon its ring B, the internal gear will be held in a fixed position, and the motion of the motor will cause the planet gears A_1 to roll around inside the internal gear in the same gears A, carrying the studs of the planet gears A, with their framework, slowly in a forward direction, as will be explained later. If all parts are locked together in any convenient manner, so as to prevent relative motion, they will then move with the motor and cause the driving sprocket R to move at a high speed forward, while if no clutch is in engagement the

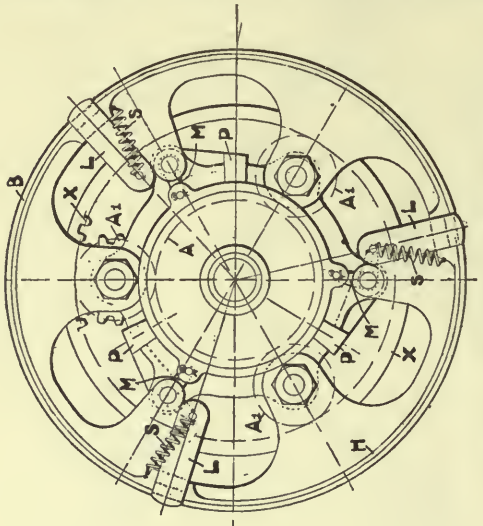


Fig. 50.—Elevation of Duryea Epicyclic Transmission Gear.

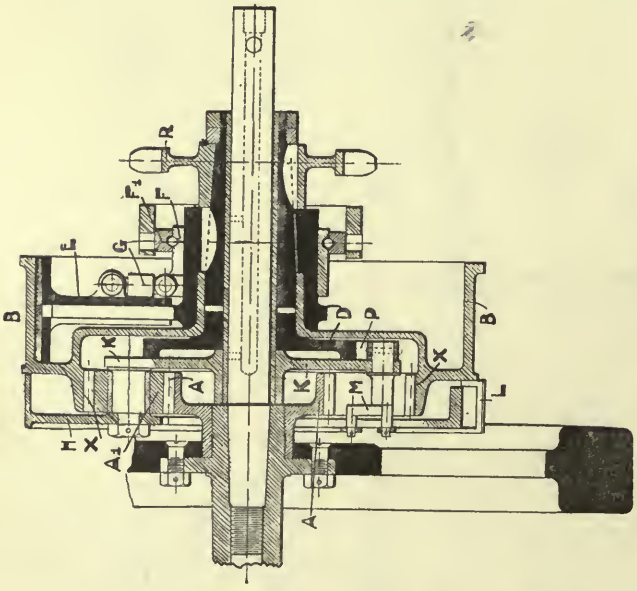


Fig. 49.—Section of Duryea Epicyclic Transmission Gear.

motion of the motor will turn the gears idly without producing motion of the sprocket.

More specifically these various motions are accomplished as follows :—The planet frame is *normally* held in engagement with the sprocket carrying disc D by means of the pins P, so that, holding the internal gear X by means of the slow-speed band,—the other clutches being released,—it carries the sprocket forward at slow speed. Since the planet gear frame and the disc D are normally in engagement, it is evident that clutching the ring X to the disc D will prevent relative motion of the planet gears and the internal gear, and thus cause the sprocket R to be carried at the speed of the motor. This effect is produced by means of clutch blocks E, engaged by complementary surfaces inside the ring B, which surfaces are brought in contact by means of a shifting collar F, and a toggle link G, a shifting lever, not shown, being attached to the outer ring of the ball bearing F_1. The section shows these surfaces in engagement ; releasing being effected by moving the shifting collar F towards the sprocket, which withdraws the blocks E and permits the surfaces to be separated. The large surfaces and toggle for closing them secure a very powerful pressure with little shifting effort, while the blocks E are ordinarily surfaced with brass, which, having a higher expansion coefficient than the cast iron against which it bears, is rapidly heated, in case of slipping, and becomes self-tightening by expansion. Releasing all the clutches allows the sprocket with its disc D and the planet gear frame to stand idle while the internal gear revolves freely in a reverse direction, although the motor may be running.

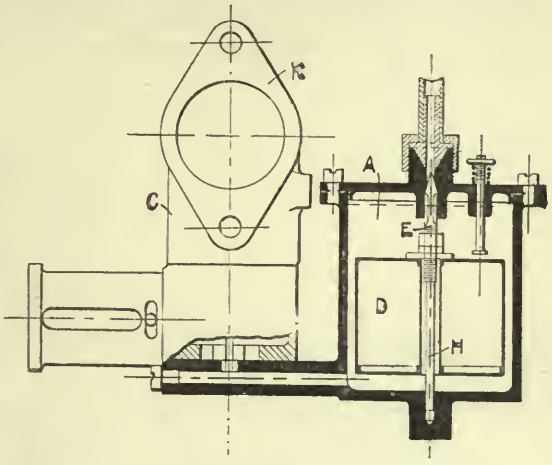


FIG. 51.—Duryea Carburetter. Sectional Elevation.

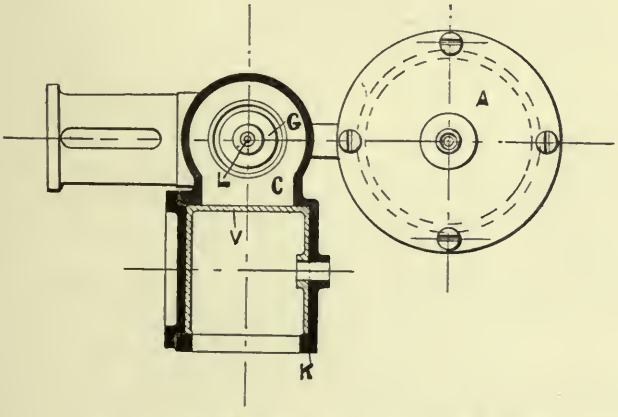


FIG. 52.—Duryea Carburetter. Sectional Plan.

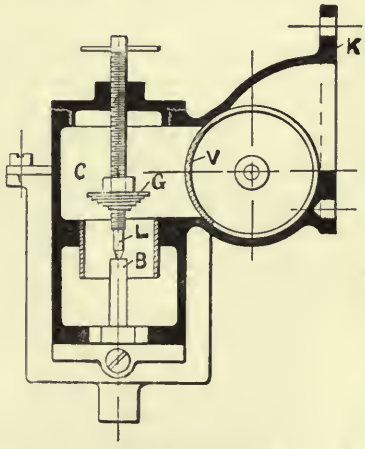


FIG. 53.—Duryea Carburetter. Cross Section.

The reversing effect is secured by holding the ring H, which is mounted on the arms of the planet gear frame, in such a manner that three sliding pieces, or plungers L (Fig. 50), normally projecting slightly above the outer surface of H, are pressed in by the gripping band, which motion moves three levers M and withdraws the pins P from

engagement with the disc D, thus separating the planet gear from the sprocket disc D. Since the band prevents further movement of the planet gear frame, while the disc D is free to move in any direction owing to the withdrawal of the pins P, it is evident that the motion of the motor will drive the internal gear X in the reverse direction, and that clutching the gear X to the sprocket disc D by means of the high-speed clutch will cause the sprocket to be carried in the reverse direction along with the gear X. It is further

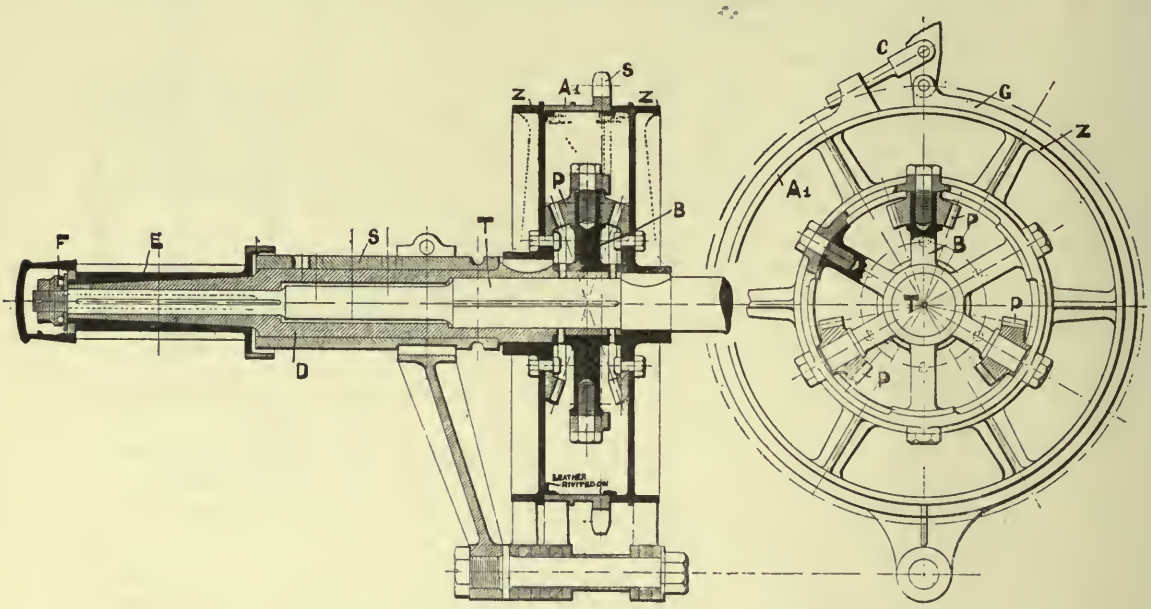


FIG. 54.—Duryea Differential Gear and Axle.

evident that releasing the high-speed clutch will stop the reverse movement of the sprocket, while releasing the reverse ring H will permit the pins P to resume their normal position under the action of their springs S.

The whole device is quite compact, and therefore readily placed by the side of the motor on a short extension of the motor shaft, which, being removable, permits the entire power gear to be quickly assembled or removed for inspection or repairs. Further, the power is transmitted from the driving gear A to the various clutch surfaces in approximately a single plane, which lessens the torsion strains on the various parts, and gives great strength with little weight of material. All parts are concentric or balanced, and therefore adapted for use at high speeds, while removable bushings secure long life. The driving sprocket is the outermost portion of the gear, and may be removed for the substitution of a larger or a smaller one by loosening a single nut after the shaft bearing is removed.

The carburetter is shown in Figs. 51, 52, and 53, and Fig. 51 shows the float chamber A in section The float D is carried on spindle H, having a needle valve E at its top end closing the petrol feed pipe. The suction from the engine is connected to flange K; the oil is drawn into the mixing chamber C through the nozzle B (see Fig. 53). It breaks up on point L, and is further broken up on the washers G. The valve V can be used to throttle the air supply mechanically.

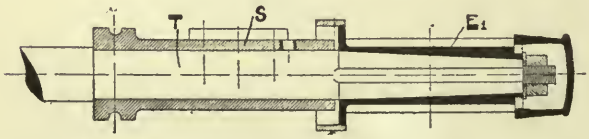


FIG. 55.—Axle.

The differential gear does not belong to the prime mover, properly speaking ; it is part of the car body, but this gear is peculiar and of interest. The brake is where it ought to be, that is, on the driver of the gear. The differential gear is carried on a spider B, as shown in Fig. 54 in end view, which also shows the brake strap G and its hangers. It also shows the three bevels P of the differential.

In the section the axles and the hollow sleeves are distinctly shown. The other end of the axle is shown in Fig. 55.

The drawings are very complete, so that the full construction of this car can readily be gathered. It is manufactured in this country, and Messrs Willans & Robinson manufacture the engines.

The horizontal engine seems to be coming into favour.

THE ALBION AUTOCAR

This car is interesting from the igniting magneto and the Murray automatic governor, which we describe fully, as they give a good general idea of the requirements in these two essentials.

Fig. 56 shows the complete magneto and the sparking—or rather in this case arcing plug, —the plugs operating by self-induction current producing an arc at the break.

Fig. 57 is a plan of the chassis showing the general arrangement and the chain gear drive to the driving wheels.

The ignition system consists generally of a magnetic electric generator driven direct from the crank shaft of the motor, generating the necessary current for the igniting spark. From the magneto the current is led to make-and-break spark plugs of simple design fixed on the combustion chamber of each cylinder, the make-and-break being operated by a trip rod and cam mounted on the half-time shaft. The magneto or generator consists of a simple hovel

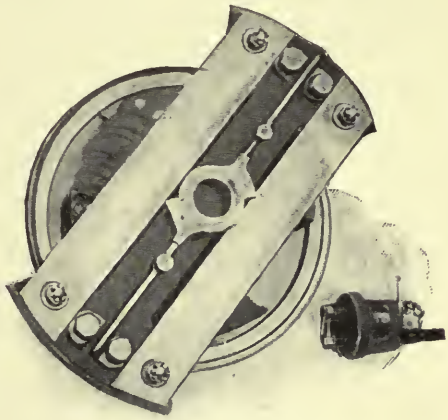


Fig. 56.—Albion Magneto.

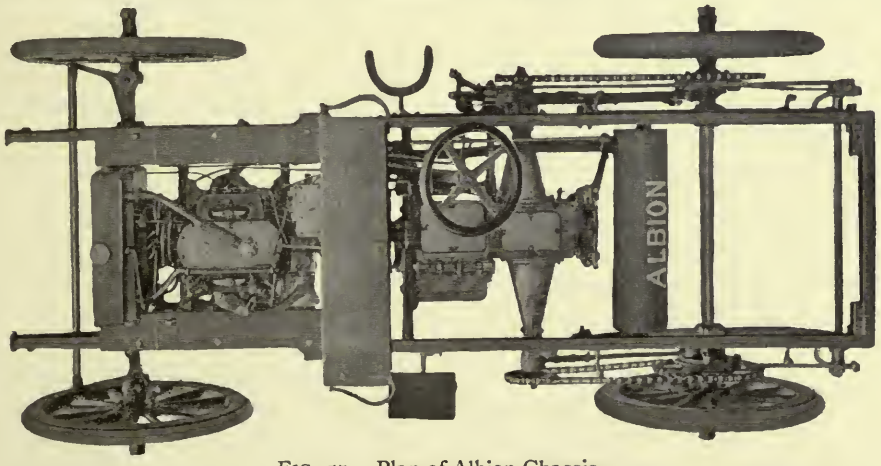
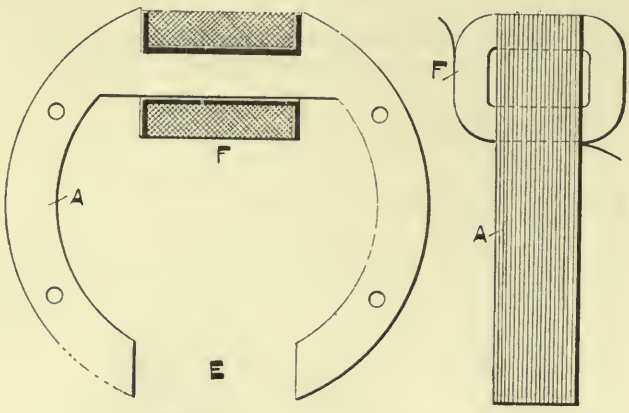


Fig. 57.—Plan of Albion Chassis.

form of ring-shaped armature bolted to the engine casing. The field magnets are mounted on a spider keyed to the crank shaft, and rotate with it. There are no moving

coils, commutators, or brushes, and therefore practically nothing to go wrong. The armature is built up of ring-shaped iron stampings, having a portion on one side entirely cut away and a portion on the other side reduced to take the armature winding or induction coil.

The field magnets consist of a couple of suitable shaped soft steel pole pieces which embrace the armature and are bolted to a non-magnetic spider keyed to the crank shaft, and across these pole pieces are bolted the necessary permanent steel magnets to produce the magnetic flux through the armature. The pole pieces being diametrically opposite each other, it is evident that as the field magnets rotate the magnetic flux will alternately pass through the armature coil in the one direction, and then in the other.

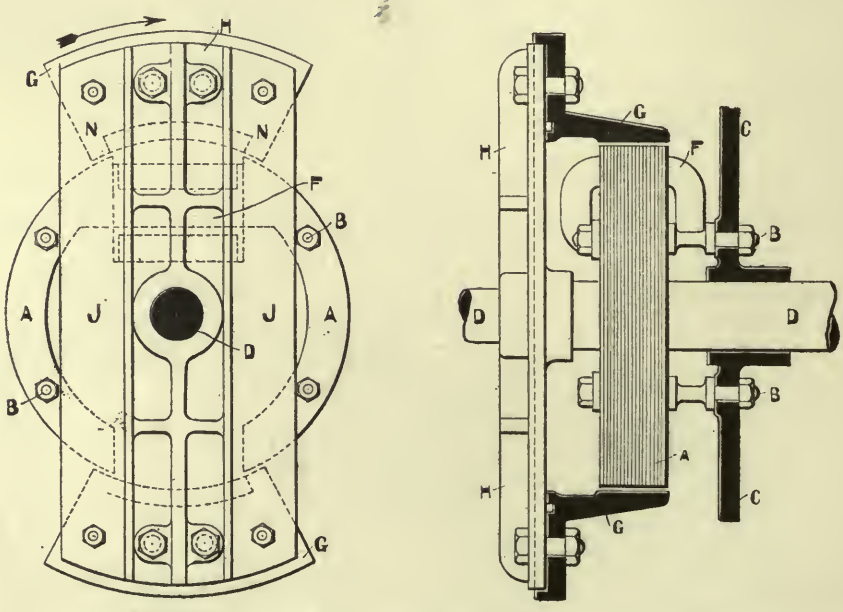


Elevation. End View.

FIG. 58.—Armature of Albion Magneto.

Fig. 58 shows two views of the armature.

A is the armature core built up of soft iron sheets of the shape shown, and bolted rigidly to the engine casing as may be most convenient. E is a portion cut away, and F shows the reduced portion to accommodate the coil.



End View. Sectional Elevation.

FIG. 59.—Albion Magneto.

Fig. 59 shows a sectional side elevation, and an end elevation of the complete generator.

D is the crank shaft of the motor, or any other shaft driven positively from the engine at the speed of the half-time shaft, or twice, thrice, or four times this speed,

as may be most convenient. To this is keyed a bronze spider H, to which in turn are bolted the soft iron or steel pole pieces G to convey the magnetic flux from the permanent magnets to the armature. JJ are the permanent magnets bolted across these pole pieces, similar poles being bolted to the same pole piece. As the field magnets rotate an alternating current is generated in the coil F, the maximum electric magnetic flux being generated just after the pole pieces have passed the position shown in the drawing.

By closing the circuit of the coil while the magnetic flux through it is a maximum, and by breaking the circuit when it is about the minimum, we get a slight magnetising effect which keeps up the permanent magnetism of the field magnets. This removes the principal objection raised against magneto ignition, that the magneto gradually weaken and require remagnetising every few months. The advantage of this feature of the system has been shown by intentionally putting on specially weakened magnets, and after months of ordinary running it was found that the magnets had increased in strength. The make-and-break mechanism is of the simplest possible description. The ignition plug proper consists of the ignition port cover carrying one insulated contact which projects into the combustion chamber, and alongside this a rotating spindle having at its inner end an arm which bears upon the insulated contact pin,—the contacts being provided with platinum tips to prevent corrosion. To the outer end of this spindle is keyed a cross-head or double-ended lever, to one end of which is attached a spring tending to rotate the spindle so as to bring the arm into contact with the insulated pin; the other end of the cross-head receives the blow from the striking spindle, which causes a sharp rupture of the circuit. This striking spindle is lifted by a simple trip cam on the half-time shaft, and it is made as light as possible, so that the lapse of time between the moment that it is freed by the cam and the rupture of the electric circuit and consequent ignition of the charge is reduced to a minimum. This has been experimentally determined and found to be less than one four-hundredth of a second.

A series of brake tests to determine whether it was necessary or advisable to provide a means of varying the time of ignition plainly showed that with a low-speed engine it was quite unnecessary with this type of ignition.

By setting the trip gear to fall when the crank has still 18° to rotate before reaching the upper dead centre, it was found that the maximum torque and brake horse-power of the engine could be got at a speed of from 550 to 850 revolutions per minute; and it was also found that with the ignition fixed at this point there was no danger of a back kick in starting, and the engine ran quite steadily and smoothly as low as 150 to 200 revolutions per minute. By setting the trip gear 27° before the dead centre, about 5 per cent. more power could be got at a speed of 950 revolutions per minute; but the power at 700 was 3 per cent. less than with the previous setting, and with the ignition set thus we found a slight risk of a back kick at starting. Practically a moderate speed motor such as ours does all its work within the range of from 500 to 850 revolutions per minute, so it is evidently quite unnecessary to provide variable ignition. Indeed, it is a distinct advantage to have a fixed ignition as the above results indicate, for it is very probable that the driver would rather lose than gain efficiency on the whole by having a variable ignition which might effect a slight saving at the top speed of the engine, but this would probably be more than compensated for by inefficient setting at lower speed.

It is also obviously desirable to simplify as far as possible the mechanism and driving of cars, and by fixing the ignition we at once eliminate one lever.

In ordinary high tension ignition there is, of course, a considerable time lag between the making of the contact in the primary circuit and the rise of magnetic flux in the coil sufficient to attract the trembler and break the circuit whereupon the igniting spark occurs, and it is principally this time lag that makes it necessary to provide

a means of varying the time at which the primary circuit is closed, or, in other words, providing a means of compensating for this time lag. As every one is aware, a careless driver can set up enormous strains on the crank shaft and other parts of the engine by running an engine with the ignition set too early, as many broken crank shafts have testified.

THE MURRAY PATENT GOVERNOR

Motor engineers have long recognised the great desirability of an engine having a wide range of speed, and further, an engine that throughout this range was self-controlling, and when once set at any speed within this range would maintain that speed without further attention on the driver's part, until alteration of speed were desired.

In the first place, owing to the fact that an internal combustion engine is not self-starting, it is desirable during short stoppages to be able to run the motor as slowly and as quietly as possible, and the usual method of doing this is to throttle down the charge and retard the ignition, but even then it is necessary to keep the motor considerably above its minimum speed, as with the above arrangement there is practically no self-recovery in the motor, as if the speed falls appreciably the likelihood is that the motor will stop through the consequent reduction of the charge. Unless this is achieved by means of a suitable governor which will automatically correct any tendency to fall below this speed, or rise above it, the minimum speed cannot be taken advantage of, with its accompanying advantages of silent running, reduction of wear and tear, and economy of petrol. Again, the minimum speed governor is very useful for giving the engine a rest on long declines when the car can be allowed to coast, and the engine to cool off on this low speed, the driver knowing that it can be instantly brought up to normal speed without resorting to the clumsy expedient of starting up through the clutch.

Centrifugal governors, such as are usually fitted to petrol engines, have really only one normal speed, and the usual method of reducing this normal speed is to introduce an external spring which acts against the main governor spring. This is a most unsatisfactory device, and can only be used within a comparatively narrow limit, as it destroys the stability of the governor.

In some engines, again, another external spring is provided whose pull is added to the pull of the governor spring, thus increasing the total pull. The objection to this being that it increases the pressure at the slip ring of the governor, and is apt to cause heating and loss of power at this part.

In many cars an accelerator device is provided by which the driver can entirely cut out the governor when so desired, but this practice cannot be too strongly deprecated, as, while it may not be objectionable in the hands of an expert, still it may be said in nine cases out of ten to be giving a careless or thoughtless driver the means of knocking the engine to pieces and reducing its useful life by more than half.

The practice of fitting no governor at all, of course, cannot be too strongly condemned.

From the above remarks it is evident that what is desired is a governor which will control the supply of fuel to the motor from full gas to no gas, either at a very low speed for halts, or at any desired speeds within a range of 30 per cent. above or below what may be called the normal speed of the engine. To meet these requirements, the Murray patent governor has been specially designed, and its principle will be readily understood from the diagram drawing annexed and the following description :—

The governor proper is of the centrifugal type, and so arranged that at low speeds the centrifugal pull of the balls is counterbalanced by a comparatively light spring. At higher speeds the balls act against a comparatively strong controlling spring, and

there may be any desired number of springs so arranged that the balls will compress them in turn at the desired different speeds. The centrifugal portion of the governor has a very long range, whereas the throttling valve has a very short range, and the connecting link between the two is of a length variable by the control lever.

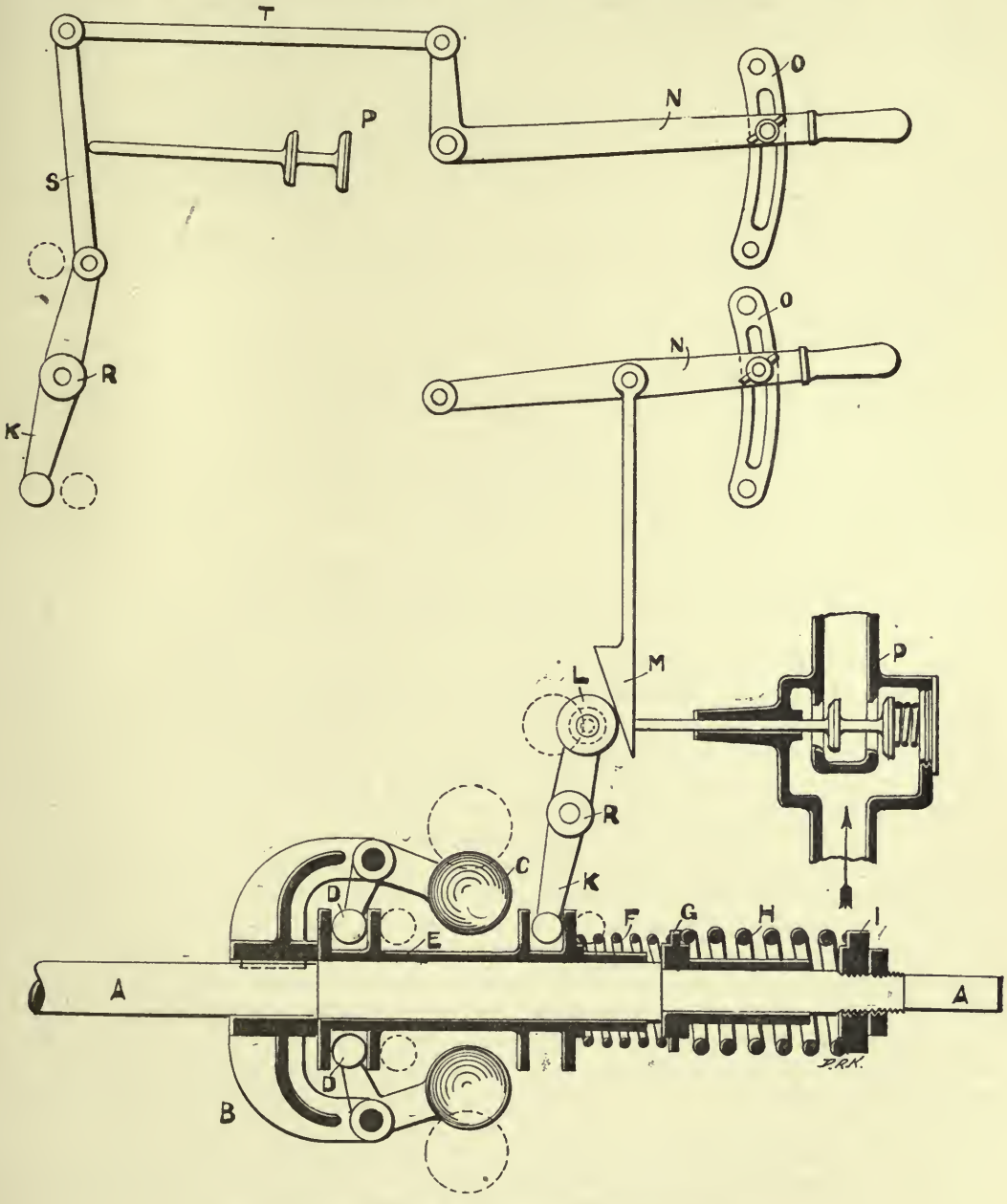


Fig. 60.—Murray Governor on Albion Autocar.

In Fig. 60 A is a shaft driven directly from the motor, and to this shaft is keyed a cross-head B which carries two governor balls CC, which are fixed to bell crank levers and pivoted to the extremities of the cross-head B. The other extremities of these bell cranks DD are mounted freely between two collars on the sleeve E, which is free to slide along the shaft A. As the shaft rotates the centrifugal pull of these balls

tends to force them outwards, and by so doing to rotate their respective bell cranks and to move the sleeve E along the shaft A from left to right. Any movement of this sleeve towards the right is counteracted in the first instance by a light spring F, which, it is evident from the drawing, will be compressed by such a motion of the sleeve. Upon the shaft A is another sleeve G, also free to slide upon it, its motion being limited towards the left by a shoulder on the shaft A and towards the right by jam nuts I. When the sleeve E has moved a slight distance towards the right on the shaft A it is evident it will come up against the second sleeve, and the centrifugal pull of the balls will tend to move this second sleeve G also towards the right, but it in its turn is forced towards the left by a strong spring H. As the spring F is a light spring, it is evident that a comparatively moderate speed of the shaft A will suffice to generate sufficient centrifugal pull in the balls to compress this light spring, and a higher speed will cause the governor to force the sleeve E up against the sleeve G and move the latter sleeve away from the shoulder and compress the spring H, a sufficiently high speed making it possible for the balls to force this sleeve right up against the jam nuts.

K is a lever pivoted about the fixed fulcrum R. One end runs between two collars on the sleeve E. It will therefore be evident that any motion of this sleeve along the shaft A will result in a movement of this lever about its pivot, and a movement in the opposite direction of its other end.

P is a throttle valve of the balance or double-beat type arranged in the inlet pipe to the motor so as to control the supply of fuel to the motor. This valve is provided with a spring, which tends to close it. The valve is sufficiently raised to give full gas to the motor.

In the position shown in the drawing M is a wedge-shaped distance piece or variable connecting link inserted between the roller L on the end of the lever K and the stem of the valve. It is pivoted at its upper end on the pin in the hand lever N. This hand lever rotates about a fixed fulcrum at one end within the limits of the quadrant O, and its position may be fixed at any point by the wing nut and bolt as shown. The motion of this hand lever downwards inserts the wedge-shaped distance piece between the end of the valve stem and the roller L, and therefore lifts the valve farther off its seat, which, of course, necessitates the lever K being rotated by the governor through a greater angle before the valve closes.

A movement of the governor sufficient to bring the sleeve E up into contact with the sleeve G will rotate the lever sufficiently to allow the throttle valve to close. It is therefore evident that the engine will govern at the low speed, as a low speed is sufficient to compress the light spring. If, however, the hand lever N is moved downwards the wedge will thereby be further inserted, and the governor will require to move the sleeve E farther to the right, and therefore also the sleeve G to the right before the valve closes. The motor will therefore govern at a much higher speed as a higher speed of the balls is required to compress the stiffer spring. This spring may be so proportioned as to give a large variety of governing speeds, the governing speed rising proportionately as the wedge is inserted by moving the hand lever downwards.

Another arrangement is shown above (Fig. 60) which achieves similar results.

In this arrangement the wedge-shaped portion is replaced by a simple lever S, the one end of this lever being attached to the afore-mentioned lever K. The other end may be moved from right to left by the afore-mentioned hand lever N.

It will be evident that as the speed of the governor increases the consequent rotation of the lever K tends to close the valve P, and also the movement of the hand lever N downwards tends to open this valve. The action of the governor is therefore exactly similar to that described with reference to Fig. 60.

In practice the governor works perfectly, and greatly simplifies the driving of the

car by making it more automatic. The driver also can tell by the position of the lever G very approximately the speed he is travelling at.

THE CROSSLEY PETROL AUTOCAR

This car has been produced by the well-known firm of Crossley Brothers, Manchester, with the assistance of Messrs. Jarrot & Letts and Mr. J. S. Critchley.

The chief features, so far as the prime mover is concerned, are a special carburetter, a special clutch and speed gear, and a cut-off regulating valve.

The new vehicle does not differ radically in general design from others constructed in accordance with the best European practice, and it is of that type in which the rear wheels are driven by side chains. A plan of the chassis is given in Fig. 61. A pressed-steel main frame, stiffened by angle plates at the corners, is employed, and the engine and the gear box are fixed rigidly and directly to it. It is mounted in the usual way on long, flat, semi-elliptic side springs, which at the rear lie just outside the frame instead of immediately beneath its longitudinal members. Both axles are very substantial forgings, having an I cross-section, and the wheels, which are of the artillery type and very strong, run on plain bearings. The rear wheels are shod with 920 by 120 millimetre pneumatic tyres, and those on the front wheels are 910 by 90. The wheel base is 8 feet 2 inches, and the track is 4 feet 8 inches.

The engine, which has four cylinders, is shown in Figs. 62 and 63. It is nominally of 22 horse-power, but develops about 28 horse-power at a normal speed of 900 revolutions per minute. Its cylinders have a bore of $4\frac{1}{4}$ inches, and its stroke is $5\frac{1}{8}$ inches. The cylinders are cast in pairs, and have unusually large water-jackets around them. The cast iron used for them is of a harder quality than that generally employed, and the pistons, too, are made of the same metal. A very special feature is made of the piston rings, which are not turned eccentric, but have an equal thickness all the way round, and are turned to precisely fit the cylinder. They are then split, and are placed in a special machine, the patent rights in which are held by Messrs. Crossley Brothers, in which they are subjected to a hammering action which gives them the necessary springiness. When in the machine they rest in a shallow cylinder, which fits them closely, and is precisely the same diameter as the engine cylinders. A hammer, having a V-shaped head, strikes their inner face with its edge at intervals all round. The force with which it strikes them automatically increases and diminishes, so that the strongest blows are dealt opposite the split, and the blows are gradually decreased in force to nothing at the split. In this way the metal opposite the split is rendered most springy, whilst that close up to it remains in its original condition, the result being that the ring fits its working cylinder exactly.

The engine has mechanically operated inlet valves arranged on the opposite side to the exhausts, and has low-tension make-and-break igniters to form the inspection covers above them. In the particular engine shown, high-tension ignition plugs are also provided, these being screwed into the inspection plugs above the exhaust valve. It is not, however, intended to equip the standard engines with the auxiliary ignition system unless specially ordered. Each cylinder casting is first faced externally, and is then bored in such a way as to ensure the parallelism of the two cylinders. It is then placed inside a box jig, where it remains during the subsequent operations which have to be performed upon it, the jig ensuring interchangeability of cylinder castings on any engine, and of all fittings on each casting.

Nickel steel is used for the crank shaft, the cam shafts, the cams, the rollers, the gudgeon pins, and the inlet valves, whilst the exhaust valves are made of a very special bronze, which is harder than ordinary crucible steel, will stand a very high temperature, and always remains clean because carbon will not adhere to it. This bronze is an alloy which is made by the firm themselves, and its composition is kept secret. The crank

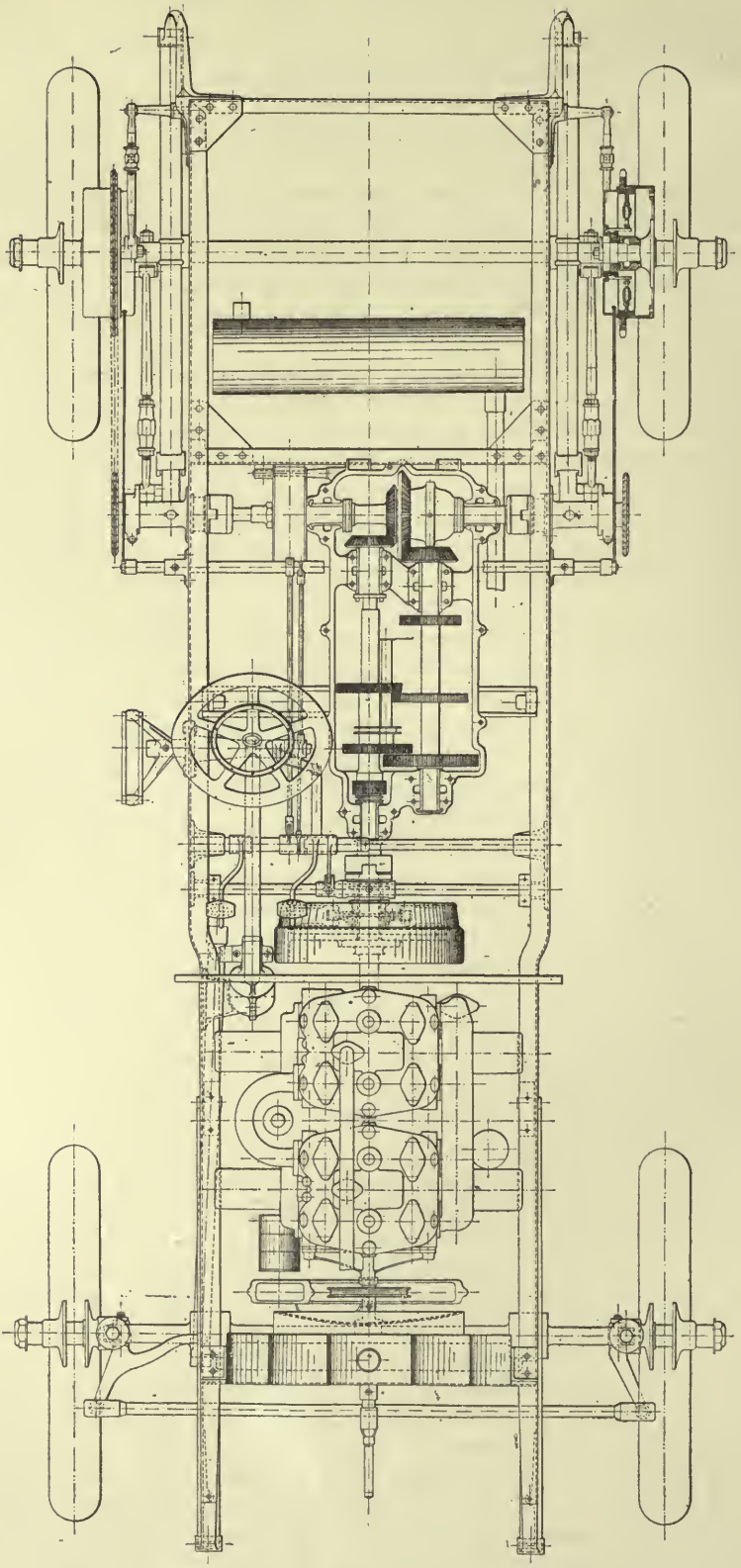


FIG. 61.—Plan of Crossley Chassis.

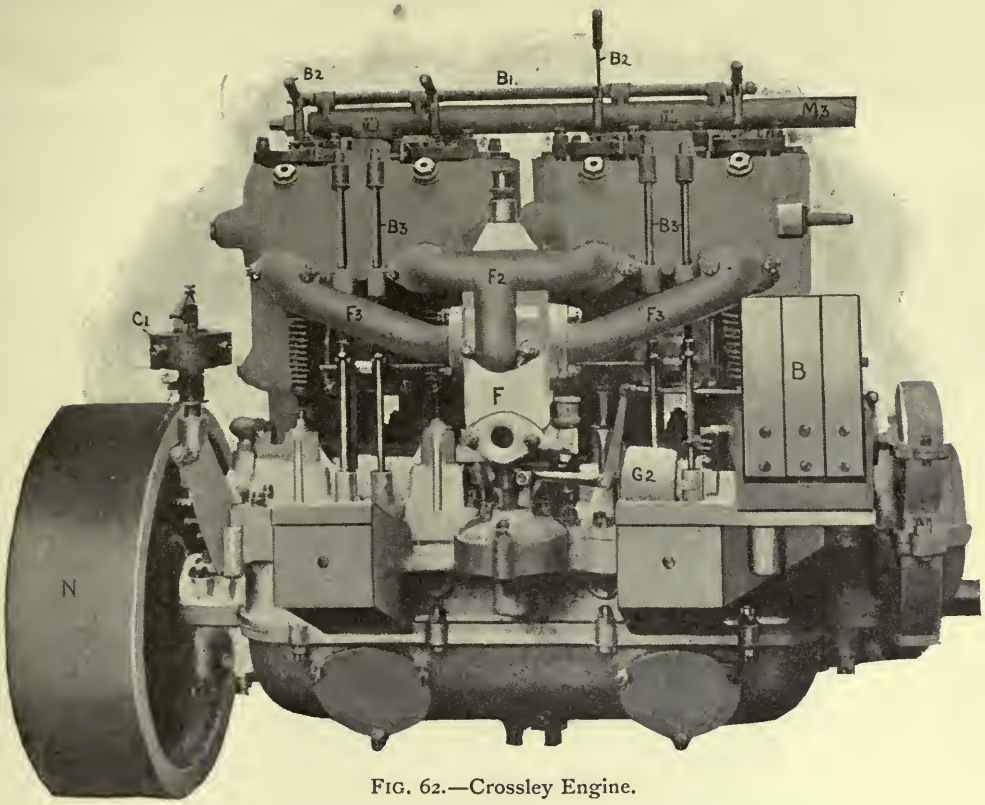


FIG. 62.—Crossley Engine.

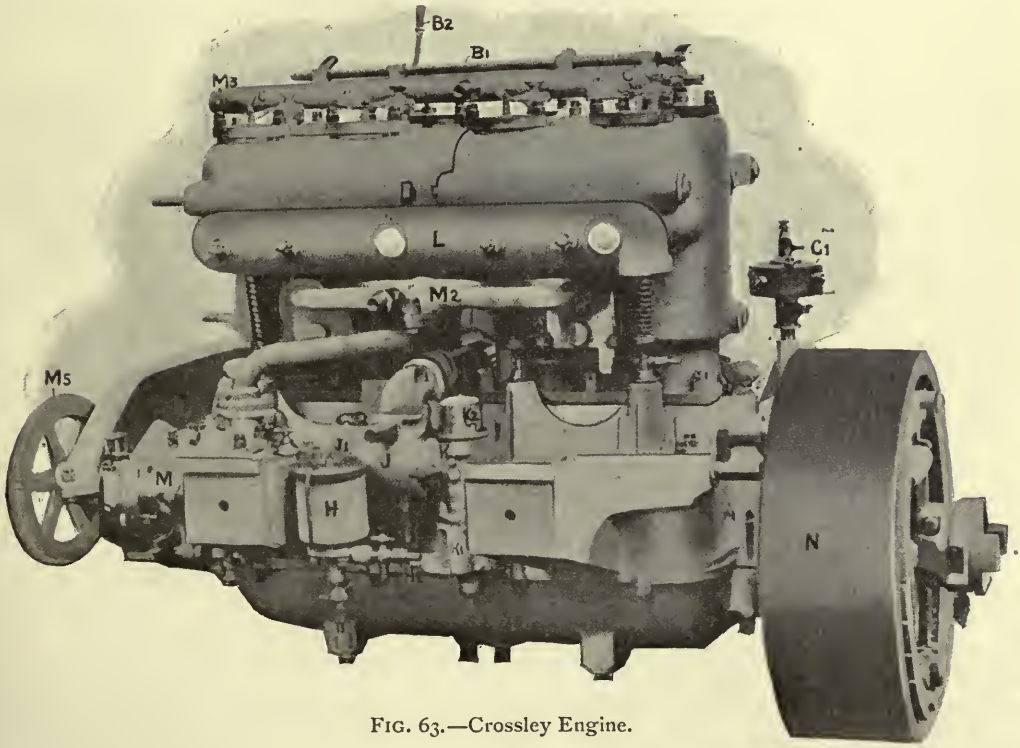


FIG. 63.—Crossley Engine.

shaft is mounted in very long bearings, and these, too, are made of a special bronze alloy, which is, in fact, used for the bearings throughout. These main bearings are ring lubricated, and the crank chamber is constructed with ducts which lead the splashed oil back again to the bearings after it has found its way into the crank shaft.

FIG. 64.—Crossley Engine Cylinder Casting. Part Section.

Liners which act as register rings, and also "break" the joint, are introduced between the cylinder and the crank chamber, and also in the joints between the induction and the exhaust pipes and the cylinder castings; those in the mouth of the cylinders also form baffle plates for preventing too much oil from being splashed up on to the pistons. The main bearing at the one end is made in such a way that any oil finding its way out along the crank shaft, through it, is caught before it can travel to the fly-wheel.

Another interesting detail in design, which is adopted throughout, is that all studs and nuts have a special thread, which is stronger than usual and is less likely to strip. The studs, too, are square between the threads, and the holes in the flanges which fit over them are also square. By this construction it is impossible for a stud to be screwed out of the casting when an attempt is made to remove a very tight nut, and all risk of breaking a stud off in the casting is practically eliminated. Castle nuts also are used, so that there is no fear of a nut shaking loose. It will be seen in Figs. 62 and 63 that the inspection plugs above the valves are fixed in this way, with square shanked studs and pinned castle nuts, and it is interesting to notice, too, that the flange portions of these plugs do not actually come into contact with the cylinder casting; they have valve-shaped seatings beneath which make a metal-to-metal joint.

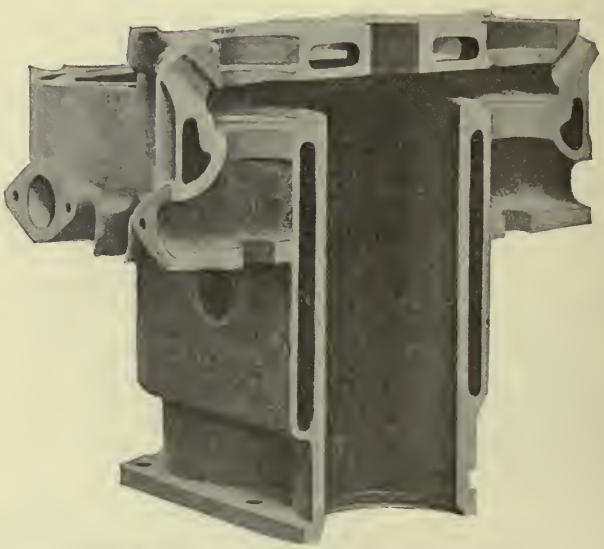


FIG. 65.—Crossley Engine Cylinder Casting. Longitudinal Section.

The gear wheels which drive the cam shafts, as also the cams, are all enclosed, and the governor is contained inside the wheel on the front end of the inlet cam shaft. The magneto B is mounted on the upper crank chamber casting, as seen, and is driven by a gear wheel in the same casing. The current generated by it is led to an insulated

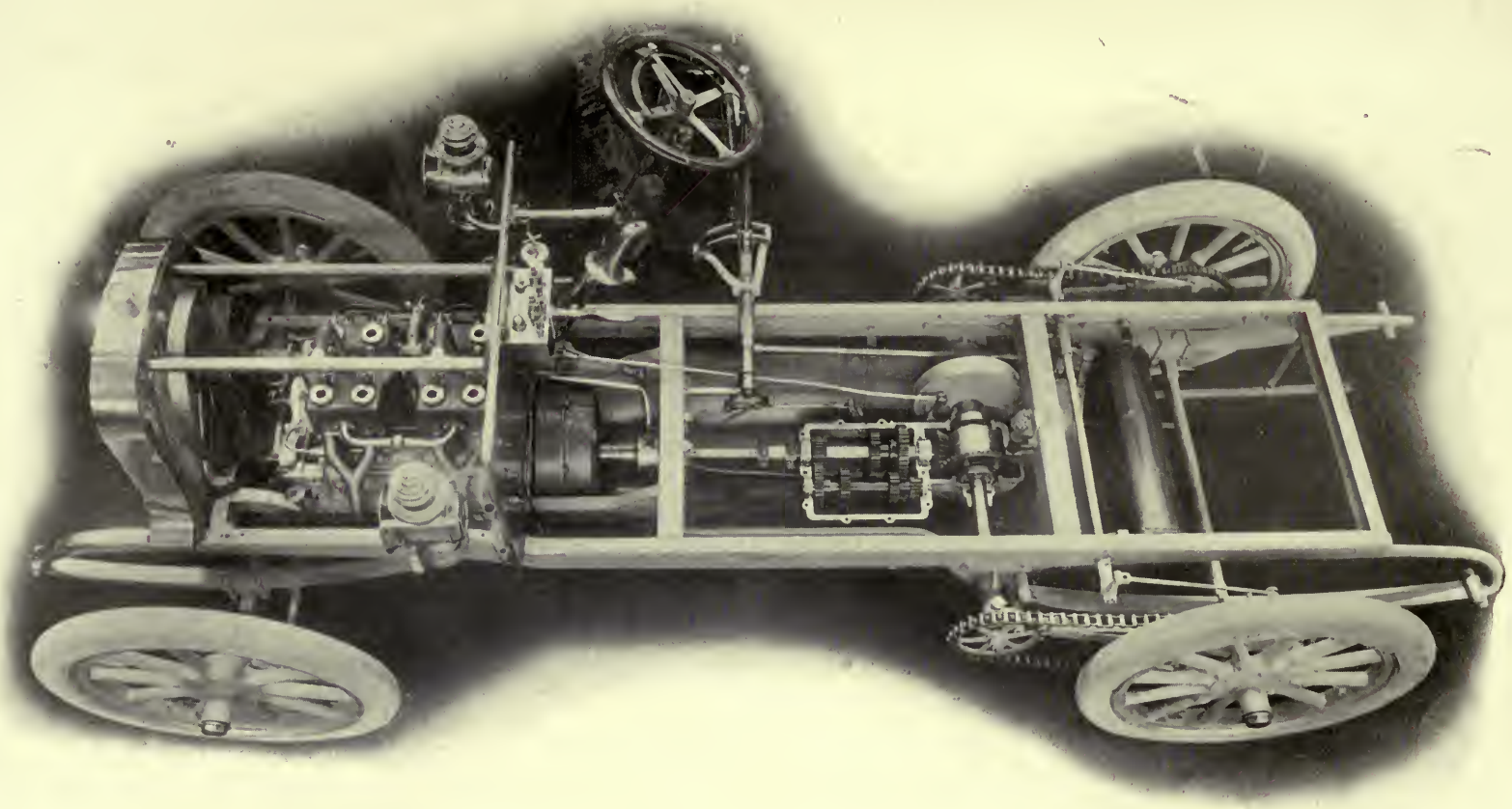


PLATE II.—PETROL AUTOCAR CHASSIS.

rod B_1, which is fixed to the water pipe M_3, and this rod has chopper switches B_2 for making connection with the low-tension igniters. The igniters are operated by disc cams on the inlet cam shaft, through vertical rocking rods B_3, which can be raised or lowered simultaneously for varying the time of ignition. The commutator C for the high-tension system is, when provided, mounted on a vertical spindle and driven by bevel gearing off the rear end of the same cam shaft.

The cylinder casting is shown cut open in Figs. 64 and 65, so as to allow the size of the water-jacket, and the unusual distance to which it extends down the cylinder wall, to be seen at a glance. It will be noticed in the cross vertical section (Fig. 66) that the inlet valves A and the exhaust valves A_1 have their seats arranged on a somewhat lower level than the port leading from them into the working cylinder, and that the gases therefore tend to pass more equally around them, instead of on the cylinder side only, this being particularly important for the exhaust valves, because it reduces the tendency for the valve to be heated to a greater extent on the one side than the other. The inlet valves are made of nickel steel, and the exhaust valves of the special bronze alloy to which we have previously referred. The induction pipes F_2 and F_3, as also the exhaust pipe fitting L, are fixed in place to the cylinder casting by studs and castle nuts, and small rings A_2 are inserted as liners to "break" the joints, and to act as register rings, which are more easy to renew than if they were formed by projections on either of the parts between which they lie. Each inlet valve is rendered easily accessible for grinding in by removing the low-tension igniter B_4, which is fitted immediately above it, and a similarly shaped inspection cover C_2 lies above each exhaust valve. These plugs are secured in place by a pair of studs passing through their flanges, but the actual joint between them and the cylinder casting is not made on the surface of the latter, but by conical valve-like seatings on a lower level, as seen in Fig. 65. In the engine shown, high-tension ignition plugs C are screwed into the inspection covers C_2, but this is not a standard practice, because it is not intended to fit a high-tension ignition system at all, unless specially ordered;

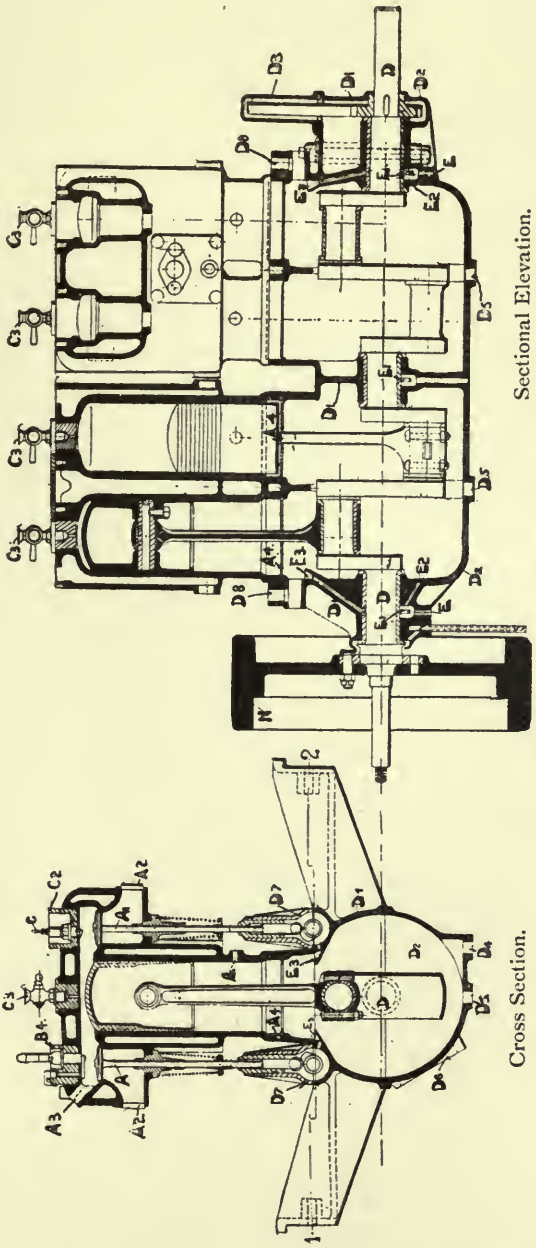


FIG. 66.—Crossley Engine.

an alternative position for the plugs is provided at A_3 in the neighbourhood of the low-tension igniters B_4, and the inlet valves A. The water is led in at the bottom of the jackets on the right side, as seen in Fig. 63, by the branched pipe M_2, and is forced out at the top into the pipe M_3 which passes across just above them. The chopper switches B_2, which make contact with the insulated terminals of the igniters B_4, are carried upon an insulated rod B_1, which is in turn supported by brackets projecting from the water pipe M_3. The igniters themselves do not call for any special comment. Half-compression cocks C_3, by which paraffin can be introduced into the cylinders to clean the rings, are mounted in much the usual way centrally in the cylinder heads. The cylinders and their pistons are made of very hard cast iron. The branched pipe, which feeds all four cylinders with oil through small, non-return ball valves from the water-jacketed pressure lubricator on the dashboard, enters each cylinder at A_5.

The aluminium crank chamber is formed by two large castings, D_1 and D_2, the horizontal joint between which passes through the centre of the main bearings of the crank shaft D. The upper portion has four projecting feet, by which the engine is securely bolted to the side members of the main frame, and the lower halves of the bearings for the cam shaft are also formed in it. Separate castings D_7 constitute the upper halves of the cam shaft bearings, and they also provide guides for the push rods to slide in. These rods having unusually wide nickel-steel rollers resting against cams of equal width ; the cams are not only keyed to their shafts, but are driven home in place with tapered surfaces between them and the shafts. The crank chamber is so shaped that it encloses the lower portions of the gear wheels driving the cam shafts, and a separate casting D_3 completes this casing. Each half of the base D_2 of the crank chamber receives small overflow pipes D_4, which project up to the required level inside the chamber, and allow any surplus oil to be drained off; ordinary drain cocks are also fitted at D_5 for completely emptying it when necessary, and inspection covers D_6 are arranged for getting at the big ends of the connecting rods.

The crank chamber provides three long bearings for the shaft D, these having split brasses of a special alloy. Each of the bearings is lubricated by a ring E_1, which circulates the oil over them from a trough in the base. The oil is led from the lubricator on the dash by two pipes to the end bearings, the pipes entering them at E. The oil finds its way from the bearings through holes E_2, into each half of the base casting, and is caught up by the connecting rods when the engine is running, and is splashed up in the usual way. The splashed oil is caught in the ducts E_3 (Fig. 66), which lead it back again to the main bearings, and also conduct it into the chambers surrounding the cam shafts and the cams. The main bearing near the fly-wheel has an oil-catching ring arranged outside it, and this ring communicates with a drain pipe as shown in Figure, so that any oil which may find its way out along the shaft is prevented from creeping on to the fly-wheel, and being scattered promiscuously by it. Air vents are provided for at D_8, at each end of the crank chamber, and the oil is prevented from being thrown up too freely into the cylinder by the baffle plates A_4, which also act as registering liners between the crank chamber and the mouths of the cylinders, as shown.

The magneto is bolted down to a bracket forming part of the crank chamber casting, and it is driven at the same speed as the engine by a small spur-wheel, meshing with the larger wheel on the front end of the inlet cam shaft ; the upper portion of the small wheel is closed in by the cover. The igniters B_4 are operated by the disc cams, these cams engaging with projecting arms mounted on the lower ends of the vertical rock shafts B_3. The arms on each pair of rocking shafts B_3 are held in contact with their cams by a helical spring connecting them together, these springs giving the quick "break" action required, the electrical circuit being completed by weaker springs on the igniters themselves. The time of ignition is varied by raising or lowering the rock shafts B_3,

so that the cams actuate them earlier or later in the cycle of operations. The "timing" is actually effected by rocking the small horizontal shaft, forked arms on which engage with small collars on the shafts B_3.

When the ordinary high-tension system of ignition is also fitted, the commutator is mounted on a vertical shaft, and is driven by a pair of bevel wheels from the rear end of the inlet cam shaft; it is mounted in the usual way, so that the time of ignition can be varied, and it is used in conjunction with four coils and a battery of accumulators.

THE CROSSLEY CARBURETTER

The special feature of this carburetter is that a column of mercury is employed to enable a more accurate and positive action to be obtained, from the suction in the

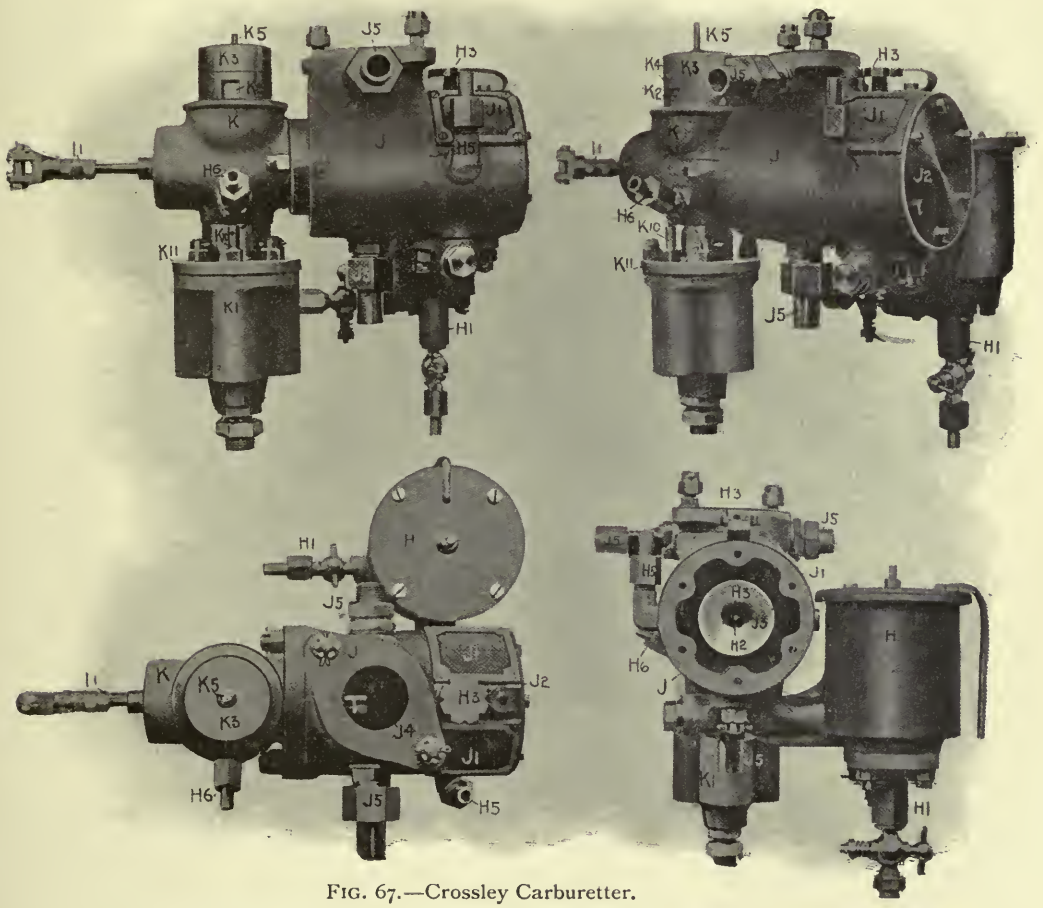


FIG. 67.—Crossley Carburetter.

mixing chamber, upon the valve which controls the admission of the auxiliary air, and to thus regulate the richness of the explosive mixture supplied to the engine. The principle adopted for ensuring a constant richness of mixture (in spite of variations of engine speed and of the quantity of mixture drawn by the engine) is similar to that made use of in several other automatic carburetters, amongst which the Krebs is perhaps the best known. It is unnecessary therefore to explain this principle at any length; it may only need be said that it is the increased suction in the mixing chamber which tends, in an ordinary carburetter, to give too rich a mixture, and

that in these automatic carburetters a valve, admitting diluting auxiliary air to the mixture formed in this chamber, is therefore arranged so as to be automatically controlled in accordance with the degree of suction, and to thus compensate automatically for such variations in richness.

In the other automatic carburetters referred to, the auxiliary air valve is connected with, or is formed by, a diaphragm or a piston, which is mounted in a portion of the mixing chamber itself, or in another chamber which is in open communication with it. The piston, or the diaphragm, as the case may be, has its one face open to the mixing chamber, and its other face exposed to the atmosphere, so that as the pressure (or, as the French more correctly call it, the depressure) in the mixing chamber is reduced below that of the atmosphere, the atmospheric pressure is caused to open the auxiliary air ports. It will be noticed that in these carburetters the actual degree of vacuum in the entire chamber acts upon the valve, and that a spring is required to hold the valve normally in its closed position. The richness of the mixture, however, does not, strictly speaking, depend entirely upon this degree of vacuum, for there are other influences at work tending to increase the flow of petrol through the jet. The spring too, when used, requires to be properly proportioned to its work, and correctly adjusted for it, besides which it is necessary that the valve (and the piston, if there is one) should move as freely and with as little friction as possible. In the carburetter with which we are now dealing (1) the automatic valve is operated in accordance with the suction produced in a pipe which resembles the petrol jet, and enters the mixing chamber close to it; (2) no spring is needed for normally closing the auxiliary air ports; and (3) the column of mercury which acts as a relay for the automatic valve renders the friction of that valve unimportant, since the force exerted upon it by the mercury is considerable.

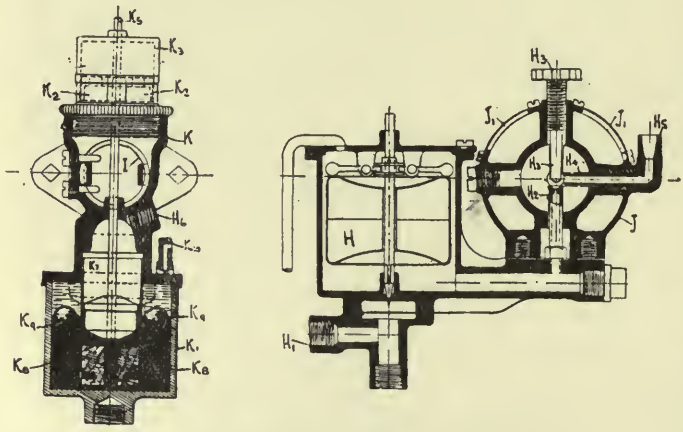


FIG. 68.—Sections of Crossley Carburetter.

The carburetter is shown from four different points of view in Fig. 67, and its entire construction is clearly indicated by line drawings in Fig. 68. In relationship to its position on the Crossley engine, Fig. 67 shows a back view, a diagonal view from behind, a view from above, and a view from the front end, in which the cover plate J_2 has been removed to show the induction passage in which the main air supply is carburetted during its passage through it.

The float feed chamber H, into which the petrol enters through the pipe connection H_1, is constructed in the usual way, and maintains a constant level of the petrol in the jet H_2, which projects up into the mixing chamber J. The mixing chamber is divided into two compartments by an induction cone J_3. The air enters the casting J through the gauze-covered holes J_1, behind the cone J_3, this end of the casting being closed in by the removable plate J_2. The casting J is water-jacketed, and the pipe connections J_5 communicate with the jacket. The air, after passing through the cone J_3 is drawn through the passage J_4 to the induction pipe F_1, its flow being controlled by the throttle valve sleeve I, which can be made to meet the cone when it is pushed forward to its full extent by the rod I_1, to which it is attached. The petrol jet H_2 projects into the cone J_3 at its narrowest point, and a needle valve H_3 is mounted immediately above

it for regulating its effective size. Another nozzle H_4 also projects through the side of the cone, close to the spray jet, and this nozzle passes to the outside of the casting J, where it terminates in the union fitting H_5, as seen. The air, entering at J_1, sweeps through the cone J_3, drawing the petrol through the jet H_2, and it necessarily has a precisely similar suction effect upon the jet H_4.

The suction jet H_4 is connected externally by a pipe, which is not fitted in our illustration with the union fitting H_6 on the casting K. This fitting H_6 leads into the lower portion of the casting K, which is partitioned off from the upper part. The casting K is screwed down into the flanged cover plate K_{11} of the mercury chamber K_1, and this cover plate fits closely down upon the top of a sleeve K_7, which acts as a partition inside the chamber K_1. The sleeve K_7 has a wooden plug inside it at the bottom, and its lower edge is slotted so as to render the interior of the sleeve in open communication with its exterior at the bottom of the chamber K_1. The wooden plug has a hole drilled through its centre to let the mercury pass through and to act as a guide for a vertical spindle K_5, which carries a wooden float K_6 inside the sleeve K_7, and at its upper end carries a piston valve K_4 in the cap K_3 above the chamber K. The shape of the mercury chamber K_1 is clearly seen in Fig. 67; the chamber is filled with mercury K_8, up to about the level shown in Fig. 68. Under ordinary circumstances the level of the mercury inside and outside the sleeve K_7 is, of course, the same, since it is continuous beneath the partition formed by the sleeve. Above the level of the mercury, however, there is no open communication through the partition K_7, and the space immediately above the float is connected, as we have already said, with the jet H_4, whilst the space outside the partition is in open communication, through a vent fitting K_{10}, with the atmosphere. Inside the sleeve the wooden float K_9 rests upon the surface of the mercury, and outside the sleeve four steel balls K_9 rest upon it to prevent splashing. The surface of the mercury is also covered with a thin film of glycerine, to prevent it from creeping and from oxidising. By this arrangement it will be seen that when the suction in the jet H_4 reduces the pressure inside the sleeve K_7 below that of the atmosphere, then the mercury inside it will rise to a higher level, carrying the float K_5 with it, and the mercury outside the sleeve will sink to a lower level, carrying the balls K_6 down with it. This occurs, of course, at the same time that the richness of the mixture formed in the induction cone J_3 increases, and at a time when more auxiliary air is consequently required for diluting it. The float K_6, being connected by the spindle K_5 with the valve K_4, gives the desired effect, because it then causes this valve to open the air ports K_2, admitting air into the central portion of the chamber K, whence it is free to pass through the throttle valve sleeve I, to mix with the over-rich charge in the induction pipe F_1. The air holes K_2 are formed in the cap K_3, in the top of which is another guide for the rod K_5, over and above the intermediate guide in the chamber K and that in the wooden plug at the base of the sleeve K_7. The level of the mercury inside the sleeve K_7 depends at all times upon the degree of suction on the jet H_4, so that the position of the auxiliary air valve K_4 is automatically controlled to give the required opening to maintain a constant richness of the mixture. The adjustments provided for enabling the carburetter to be set to suit the engine to which it may be fitted consist of the needle valve H_3, which regulates the effective size of the spray jet H_2, and of means for changing the position of the valve K_4 relatively to the spindle K_5.

The bore of the cylinders is $4\frac{1}{4}$ inches, and the stroke of the pistons is $5\frac{1}{8}$ inches. A compression of approximately 75 lbs. per square inch is arranged for, and the engine develops about 28 brake horse-power at its normal speed of 900 revolutions per minute. It is capable of doing useful work at any speed between 80 and 1200 revolutions per minute, this wide range being largely due to the special carburetter with which it is fitted, and to the employment of mechanically operated inlet valves. The studs by which the various detachable parts are held in place have a square cross section, except at their threaded ends, and as the flanges which fit over them have corresponding square

holes through them, it is impossible for a stud to be broken off in the casting, or to be screwed out of it, when tightening up or slackening the nut; a specially strong screw thread has also been adopted for all the studs, so that they are less likely than usual to have their threads stripped. The nuts employed are of the "castle" type, which permit split pins to be introduced for locking them, whatever their position may be, when they are tightened up.

CROSSLEY'S VARIABLE CUT-OFF VALVE

The object of this valve is to enable the volume of the charge which is drawn into the working cylinders of the petrol engine to be varied, and yet to maintain a full opening between each cylinder and the carburetter during the whole time that any charge is being drawn in. By this means the fuel consumption is reduced when the engine is running on light loads, and constancy in the richness of the mixture does not depend to any great extent upon the perfection of automatic devices in the carburetter itself. The difference in effect between a variable cut-off mechanism of this description and an ordinary throttle valve is that in the former case the volume of the charge depends but little upon the actual speed at which the engine is running, whereas, with a throttle valve, the amount of mixture drawn into the cylinder varies as the engine speed varies.

The main portion of the Crossley valve is seen in Fig. 69, and the complete mechanism, together with the gear wheels driving it, is shown sectionally. Referring to these illustrations, F is a cylindrical casting, into a base of which the induction pipe F_2 from the carburetter passes. The mixture normally passes freely through the casting, and is conducted by pipes F_2 and F_3 to the four cylinders, the former leading to the two inner cylinders, and the latter branching off right and left to the two outer cylinders. Each pair of cylinders grouped in this way operate at the same moment alternately for each revolution, and therefore, so far as the cut-off valve is concerned, this device may be regarded as though it were controlling the passage of the explosive charge to two cylinders only—each giving an explosion every revolution—and set with its crank opposite the other.

The port opposite the induction valve F_1 is closed by a cap F_4, this being only provided for use on engines in which it is more convenient to bring the induction pipe F_1 in at this side than at the other.

The cylindrical valve F_5, which fits inside the casting F, is fixed to the vertical spindle F_7, by which it is caused to revolve. The spindle is so mounted that it can be moved up and down in its bearings, carrying the valve with it. The valve revolves at the same speed as the crank shaft of the engine, and is driven by the spiral gear wheels F_9 and F_{10} off the inlet cam shaft, a feather key being fitted between the wheel F_9 and the spindle F^7 to allow the latter to slide.

The valve F_5 is formed with a large wedge-shaped port F_6, and similarly shaped cavities are provided on either side in the casting F, where the pipes F_2 and F_3 are connected with it. The lower portion of the valve F_5 forms a cylindrical guide, and is like a ring through which there is always free communication to the port F_6. As the valve revolves, the port F_6 in conjunction with the cavities in the casting F always affords an open passage for the explosive mixture to the pipes F_2 and to the pipes F_3, at the beginning of the suction stroke in the cylinders to which they are respectively connected; but it will readily be understood that the flow of mixture to the cylinders will be cut off earlier or later by the sloping edges of the ports according to the vertical position of the valve F_5 inside the casting. When this valve is in its uppermost position (as in Fig. 69) the through passage is only closed at the end of each suction stroke, the port F^6 being then open to the pipes F_2 during one half revolution of the valve F_5, and being open to the pipe F_3 during the second half revolution. As the valve is lowered, however, the passage of the gases is cut off earlier and earlier in the

stroke, with the result that a partial vacuum is formed during the latter portions of the inlet strokes in the working cylinders.

The valve F_5 is raised and lowered by a forked bell crank lever, which engages in a groove in the sleeve F_8, this sleeve being fixed to the spindle F_7. In the engine shown

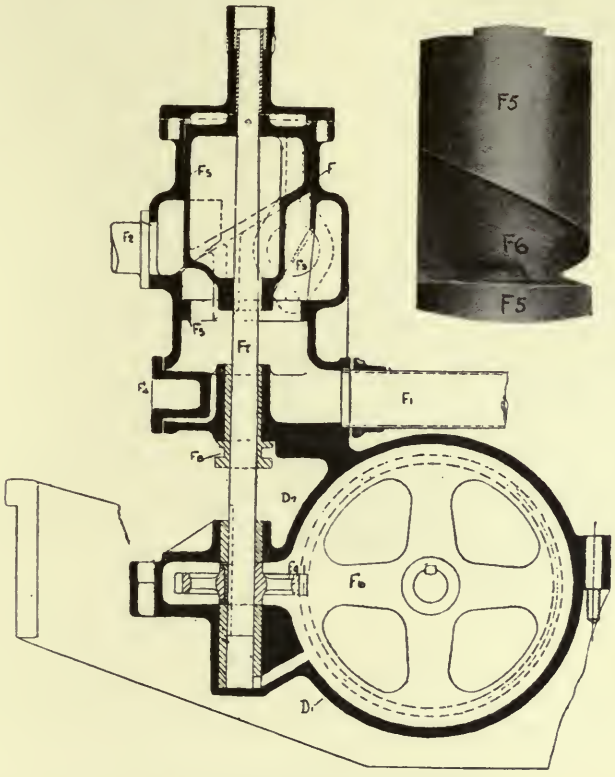


FIG. 69.—Crossley Variable Cut-off Valve.

in the illustrations the bell crank lever referred to carries a counter-weight G_2 (Fig. 62), which balances the weight of the valve F_5. The valve is connected with the centrifugal governor, so that it lowers the valve F_5 as the engine speed increases.

THE DE DION-BOUTON ENGINE AND CARS

This celebrated firm's manufactures are almost too well known to require description. Several features are, however, well worthy of the attention of engineers. And no work on autocars would be complete without reference to the De Dion inventions, even although they are so well known

Fig. 70 shows the De Dion-Bouton 2-cylinder engine complete as fitted into the cars.

Figs. 71, 72, and 73 show the 2-speed and reverse gear.

In Fig. 71 we have a vertical section of the aluminium gear box AAAA, the rear or right-hand portion thereof forming the forward half of the case enclosing the bevel gearing PP and P^1P^1 and the differential gear. Running through the upper part of the gear box is seen the primary gear shaft BB, rotating in its double ball bearings B^1B^1. Outside the case, on the left hand, is one half B_2 of the universal joint, by which the primary shaft BB is connected to the propeller shaft, which is attached at its other end to the crank shaft of the engine. The primary shaft BB is formed with feathers thereon, to allow of the lateral movement of the sleeve carrying the high-speed driving

pinion EE. On the shaft itself is formed the reverse driving pinion F, and just to the right of the left-hand ball bearing is seen the low-speed driving pinion DD, which is keyed fast to the shaft BB. Immediately below the primary gear shaft BB is the secondary hollow gear shaft CC, also running in double ball bearings C^1C^1.

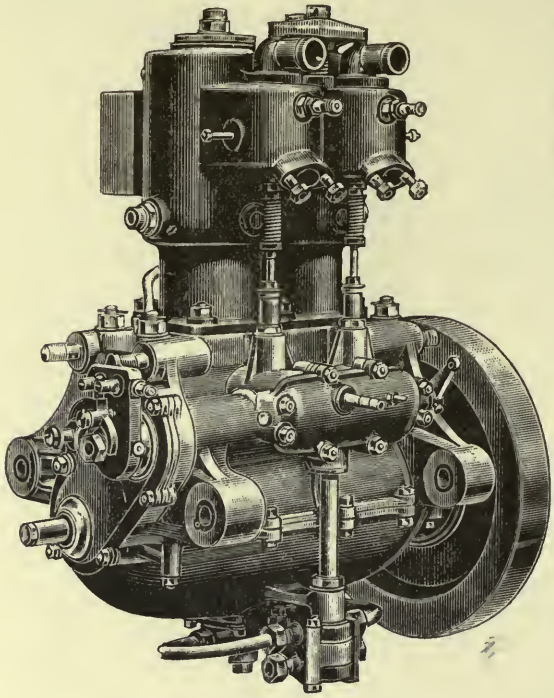


FIG. 70.—De Dion-Bouton Engine.

Commencing from the left-hand side, just outside the gear box, this shaft is seen to carry the brake drum O, and within the box the low-speed clutch box GG, to which is attached the low-speed gear wheel D^1D^1, which is free on shaft CC. The grooved collared sleeve LL, to which is attached the reverse speed clutch box II carrying the gear wheel F^2F^2, which is rotated by the intermediate pinion F^1F^1, this later pinion being located in the middle of the gear box (see Fig. 72). Farther to the right the shaft carries another grooved collared sleeve LL, upon which is mounted the high-speed clutch box HH, carrying the high-speed driven gear wheel E^1E^1. Beyond its right-hand ball bearing the shaft CC carries the driving bevel wheel PP, which meshes with the bevel wheel P^1P^1 shown in the partial horizontal section below the figure.

Within the hollow of the shaft CC is placed the rack, which, moved one way or the other, serves, by means of the pinions KKKK, to expand one or the other pair of the

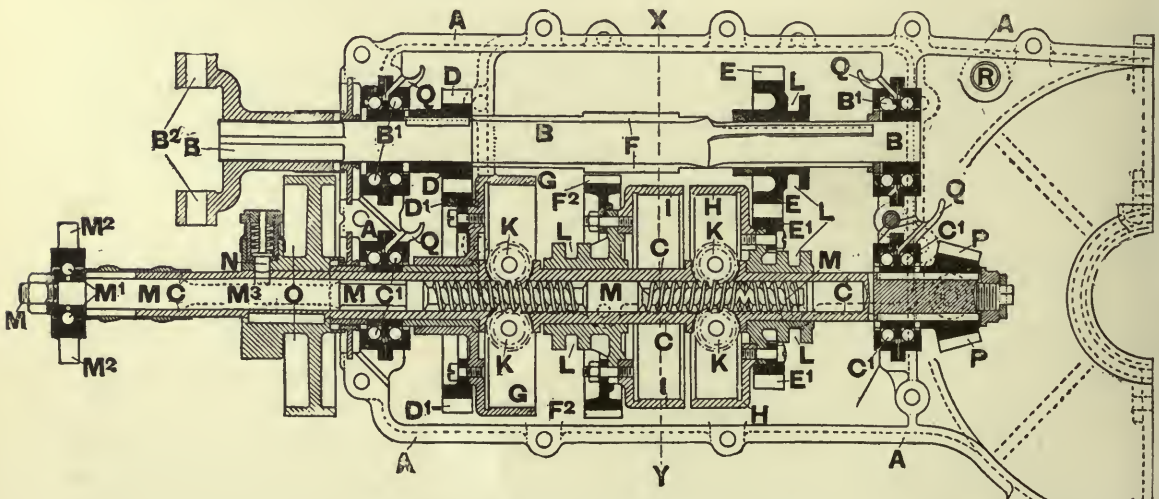
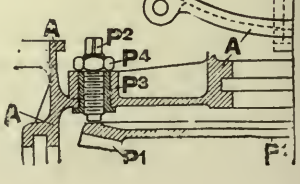


FIG. 71.—Longitudinal Section of De Dion-Bouton 2-Speed and Reverse Gear.



fibre-covered segmental expanding clutches, one pair of which is shown in Fig. 72, and marked I^1I^1.

Now, to detail the manner in which the low and high ratios of drive are conveyed through the shaft C to the bevel wheel PP.

The low-speed driving pinion DD on the primary gear shaft BB is always in mesh with the low-speed driven pinion D^1D^1 attached to the low-speed clutch box GG. The movement of the gear-striking lever to the low-speed position gives the rack MM a movement which rotates the pinions KK within the clutch box GG, so as to expand the segmental clutch within that box and lock the same up to the shaft CC. The same movement has similarly withdrawn the expanding clutch from contact with the inner surface of the high-speed clutch box HH, so that the drive can only pass to the bevel wheel PP through the gears DD and D^1D^1, clutch box GG, and the shaft CC, and thus the slow speed is obtained. To put in the high speed, the speed lever being moved to the high-speed position, a reverse movement is given to the rack MM, which has the effect of withdrawing the clutch within the clutch box GG from contact therewith, and expanding the clutch within the high-speed clutch box HH, until the latter in its turn is locked up to the shaft CC. The engine drive then passes through the primary shaft BB, the high-speed driving pinion EE, and the high-speed driven gear wheel E^1E^1, which is attached to the high-speed clutch box HH, already locked up to the secondary shaft CC by the expansion of the clutch within it. And so the high-speed drive accrues. Now we come to the reverse, which is obtained in a particularly neat and ingenious manner. The gear striking lever is moved to the free gear position, the rack MM being thereby so actuated that both expanding clutches within the clutch boxes GG and HH are withdrawn from contact with their respective clutch boxes. Then by pressing a pedal with the right heel the small arm T (Fig. 73) is actuated in such wise that by means of the link T^1T^1 the striking forks attached to the sliding sleeve S_1S_1 sliding on the shaft SS (Fig. 73), which forks engage with the collars LLLLL (Figs. 71 and 73), cause the high-speed pinion EE and the clutch boxes HH and II, with all they carry, to slide together sufficiently to the right to bring the clutch box II over the expanding clutch shown within clutch box HH in Fig. 71. The same clutch is then expanded by the requisite movement of the rack MM, and the reverse speed clutch box II is thereby locked up to the shaft CC. Now the intermediate pinion F^1F^1 (see Fig. 72) is already in mesh with the pinion F on the primary shaft BB, so that the drive now passes from the shaft BB through the pinion F, the intermediate pinion F^1 (Fig. 72), and the pinion F^2 attached to the clutch box II, which, as we have already shown, is locked up to the shaft CC by the expanding clutch over which it has been moved. The expansion of this clutch has already been described in detailing the high-speed drive. The whole of the gear within the gear box is served

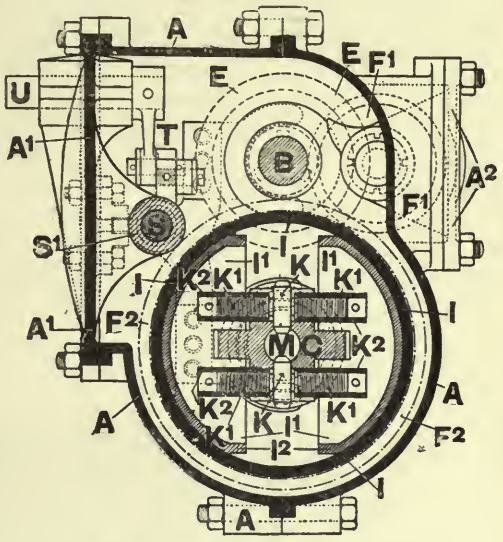


FIG. 72.—End Section of the Gear.

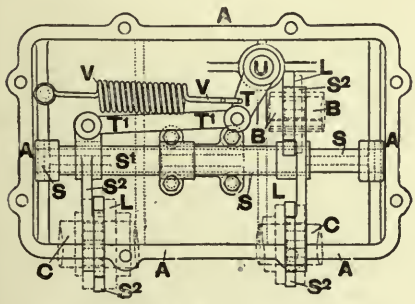


FIG. 73.—Details of Reverse Gear.

by dash lubrication, and the four catch channels, with the leads to the four ball bearings, are plainly shown in Fig. 71.

Fig. 74 is a complete view of the 2-speed gear without the reverse.

Combinations obtainable in the 2-speed and reverse gear.

Revolutions of the motor are reckoned at 1600 a minute.

Diameter of the wheels is reckoned at 700 millimetres, or 27½ inches.

High-speed combination is 27 driving 33.
Low-speed ,, 17 ,, 43.
Reverse ,, 12 ,, 55.

Gear.	Bevel.		High Speed.		Low Speed.		Reverse.	
Letter.	Pinion.	Wheel.	Kilos.	Miles.	Kilos.	Miles.	Kilos	Miles.
A	17	80	32.05	20	15.58	9¾	8.55	5¼
B	16	71	36.10	22½	17.45	11	9.63	6

Fig. 75 illustrates the arrangement of the gear designed to give three speeds forward and a reverse. BB, the primary feathered gear shaft, carries a sliding sleeve

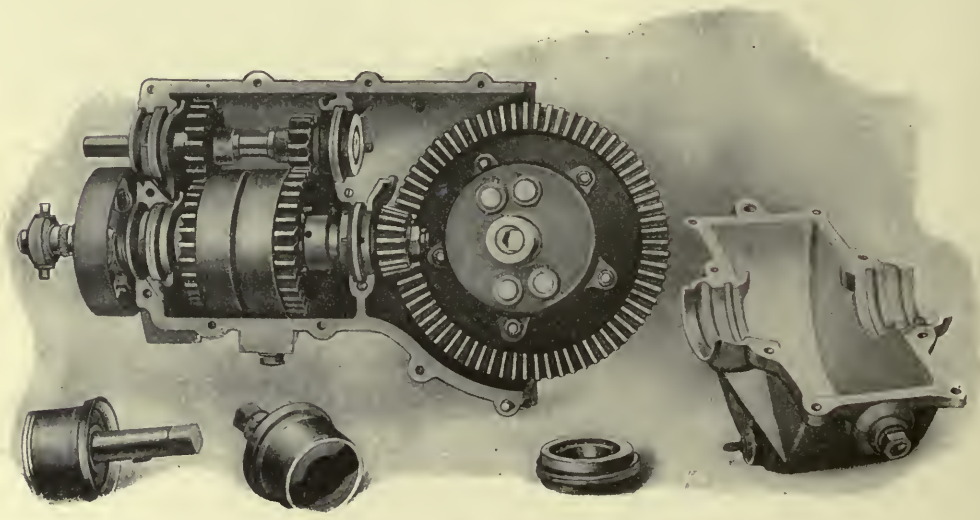


Fig. 74.—Two-Speed Gear without Reverse.

D^1D^1, upon which are mounted the toothed driving pinions 1, 2, and 3. On the left we find a pinion marked 4, which is the driving pinion of the reverse speed.

On the secondary shaft below CC, within the gear box, are two of the well-known expanding clutches, by one or other of which the secondary shaft CC is rotated. Attached to the three sleeves sliding on the secondary shaft are the clutch boxes—the first speed clutch box HH, the second speed clutch box KK, the third speed clutch box II, and the reverse speed clutch box LL. Each of these clutch boxes (as can be seen) carries attached to it the driven pinions of 1^1 of the first speed, 2^1 of the second, 3^1 of the third speed, and 4^1 of the reverse respectively. The 1 and 1^1, 2 and 2^1, 3 and 3^1 are always in mesh, no matter which particular pair are being driven through, because the sliding D^1D^1 on the primary shaft and the sleeves upon which the clutch boxes I, H, and K are mounted always move together.

Let us suppose that it is desired to drive upon the first speed, *i.e.* through the toothed wheels 1 and 1^1 and the clutch box HH. By the actuation of the gear pedal, the sleeve D^1D^1 and the sleeves carrying the clutch boxes I, H, and K are slid to the right until the clutch box H encloses the expanding clutch H^1. A movement of

the clutch lever then expands clutch H^1 within clutch box H, and contracts the clutch M within the clutch box LL. So we have the first speed.

Now for the second. A movement of the change gear level to the middle position frees the clutch, and the sliding sleeves on both shafts are brought back to the position shown in the drawing. By a further movement the clutch H^1 is contracted within the clutch box II, and the clutch MM expanded within the clutch box KK. Now the drive passes from the pinion 2 through the toothed ring 2^1, the clutch box K to the shaft CC by means of the clutch MM. Thus we have the second speed.

To obtain the third speed, no movement of either of the sleeves is required, but the reverse movement of the change gear lever causes the clutch M to contract and the clutch H^1 to expand. Then the drive passes from the driving pinion 3, through the toothed ring 3^1, and the clutch box II, to the shaft CC, by means of the clutch H^1H^1. Thus we have the third or high speed.

To obtain the reverse, the actuation of the change gear pedal causes the sleeves on both shafts to move to the right exactly as they did in the case of the first speed; but the action upon the clutch expanding and contracting rack NN is reversed, — that is to say, by the movement of the change gear level the clutch M is expanded within the clutch box LL, and the clutch H^1H^1 contracted within the clutch box HH. The drive passes from 4 through the intermediate pinion (not shown), the toothed wheel 4^1, the clutch box LL, to the shaft CC by means of the clutch MM. Thus the shaft CC is rotated in a direction opposite to that in which it is driven by the previously explained combinations.

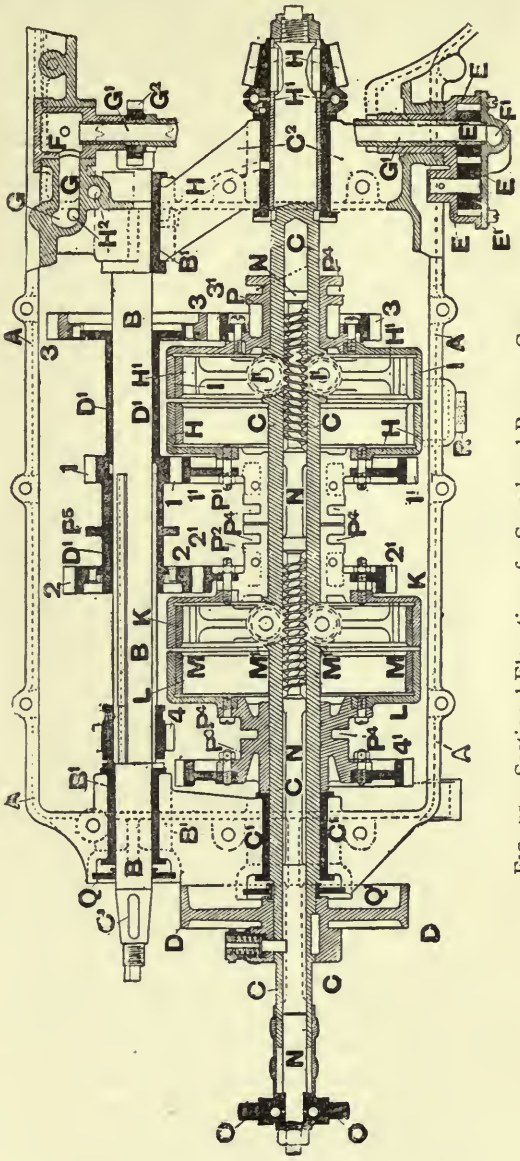


Fig. 75.—Sectional Elevation of 3-Speed and Reverse Gear.

Combinations obtainable in the three-speed and reverse gear 12 horse-power motor carriages, Model S:—

Revolutions of the motor are reckoned at 1500 a minute.

Diameter of road wheels is reckoned at 810 mllimetres, or 32 inches.

High-speed combination is	30	driving	30.
Middle-speed	,,	24	,,	36.
Low-speed	,,	16	,,	44.
Reverse	,,	18	,,	51.

Gear. Letter.	Bevel. Pinion.	Bevel. Wheel.	High Speed. Kilos.	High Speed. Miles.	Middle Speed. Kilos.	Middle Speed. Miles.	Low Speed. Kilos.	Low Speed. Miles.	Reverse. Kilos.	Reverse. Miles.
A . . .	18	90	43.00	26¾	28.65	17¾	15.63	9¾	15.17	9½
B . . .	20	90	47.80	29¾	31.80	19¾	17.37	10¾	16.86	10½
C . . .	22	90	52.50	32½	35.00	21¾	19.10	11¾	18.54	11½
D . . .	24	90	57.30	35½	38.20	23¾	20.80	12¾	20.23	12½

De Dion-Bouton motors are exactly the same in principle as the universally known 4-cycle gas engines. They were the first of the high-speed type. It is by reason of their high speed, combined with the quality of workmanship, that these motors develop such extraordinary high powers in proportion to their size and weight. At first engineers were prejudiced against them, and prophesied that motors running at such speeds would wear out in a very short time. The result, however, has proved that they were entirely in error, as the motor has a long life, and even when worn the working parts can be renewed at a very small cost. The success of the motors, and the fact that all motor vehicles are gradually being built with motors approaching them in speed, are ample proofs that they are made on correct principles.

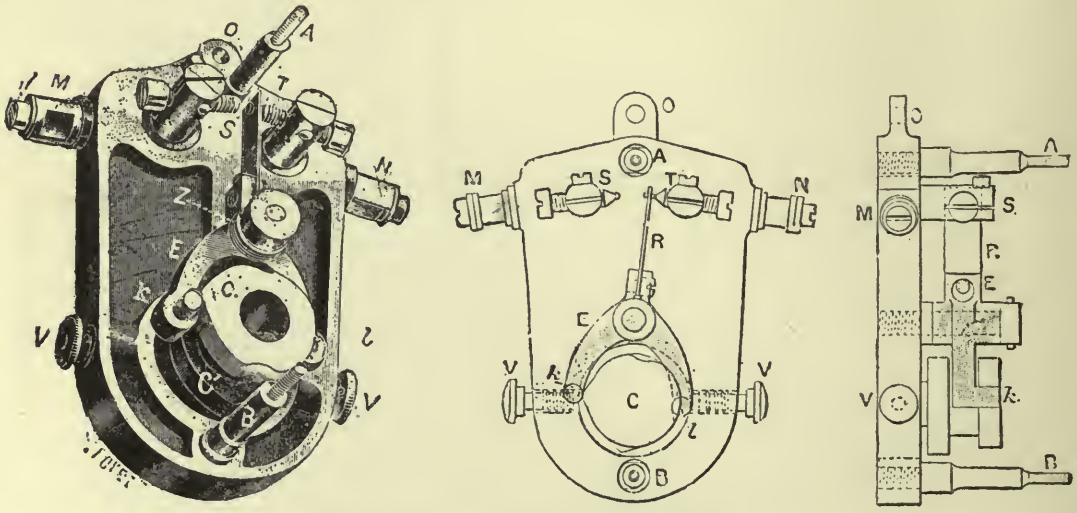


Fig. 76.—De Dion-Bouton Contact Breaker.

The explanation ot the wear resisting qualities of the motors is very simple. In an ordinary slow running motor only about half the number of explosions take place per minute as in the De Dion-Bouton. Each explosion must give at least twice the impulse, and the thrust on the bearings must therefore be at least twice as great.

Ignition.—Electric ignition, now universally used, was first introduced in a practical form by Messrs. De Dion-Bouton et Cie. on their earliest petrol motors. The system they adopted is known as the high tension. The current is generated by a special 4-cell dry battery and intensified by a powerful induction coil. Whereas other systems of breaking the primary current consume a considerable amount of electricity, the patent contact breaker is so economical that a dry battery can be used instead of the usual accumulators, thus eliminating a continual source of trouble and annoyance.

Contact Breakers.—In the single cylinder motors the well-known patent trembling contact breaker, the same that has been fitted to all motors, except the 2-cylinder, is used. The vulcanite is now replaced by a metal base plate, one terminal being insulated and the other dispensed with.

The 2-cylinder motors are fitted with a new form of contact breaker which is very easily adjusted and works with great regularity. The contact is so short, and therefore economical, that dry-batteries are used with them. In Fig. 76 it will be

seen that the contact blade R is mounted on a two-armed lever E, actuated by two cams C, C^1, fixed on the half-time shaft, which cause the blade to make contact with the contact screws ST.

As in the single cylinder motors, the whole contact breaker can, by means of the spring bolts, be detached from the crank case and slipped over the cams.

Index to Fig. 76:—

A, B, Pillars by which cover of contact breaker is fixed.
C, C^1, Two cams on half-time shaft.
E, Double arm lever carrying blade R actuated by cams C, C^1.
k, *l*, Studs on lever E engaging with cams C.
M, N, Positive wire terminals. (The return is made through plate of contact breaker.)
Q, Connection for rod to move contact breaker.
R, Spring blade with double-sided platinum contact stud.
S, T, Contact screws.
V, V, Spring bolts engaging with slots in crank case and securing contact breaker.

Exhaust Valve Regulator.—All De Dion-Bouton motors are now fitted with a movement regulating the lift of the exhaust valve. By this system the volume of the exhaust can be reduced as desired, with the result that the incoming charges of fresh gas are reduced in proportion but without affecting the compression. This arrangement gives the driver wonderful control, and enables him to adjust the power of the motor to the work, at the same time reducing the consumption of petrol and the noise and vibration to a minimum.

Fig. 77 illustrates the exhaust valve regulator as applied to single cylinder motors. A lever on the front of the half-time case actuates the piece D^4, which, by means of the small pivot on which the arm D works, causes the latter to be advanced.

The exhaust valve is opened by the cam C, raising the lifter A, the position of the thickened end of the arm D regulating the height of the opening. The position for the full or normal lift is shown in Fig. 77. In this the arm D is advanced, and the amount of the lift is reduced to the minimum.

In the 2-cylinder motors the lift of the exhaust valves is controlled in an exactly similar manner.

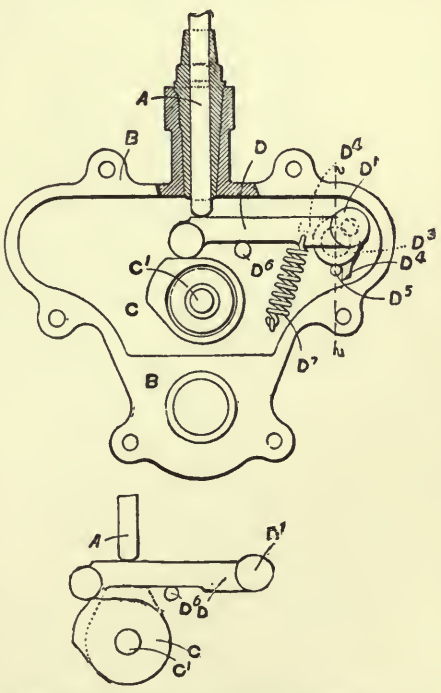


FIG. 77.—De Dion-Bouton Exhaust Valve Regulator.

The lever at a tangent to the cam has a considerable advantage over some other arrangements in which the valve rod comes down direct upon the cam diametrically, in which case there is an enormous side thrust on the valve rod. This is obviated by the tangential contact.

Carburetter.—The De Dion-Bouton patent spray carburetter is designed to give the most effective results with unusual freedom from complications.

The petrol enters at 3 (Fig. 78) and passes through the tube E to the float chamber

and spray. As soon as it has risen to its proper level the float (which by means of a small lever balances the weighted needle F) rises and allows F to descend and so close the opening by which the petrol enters, and thus a constant level is always automatically maintained.

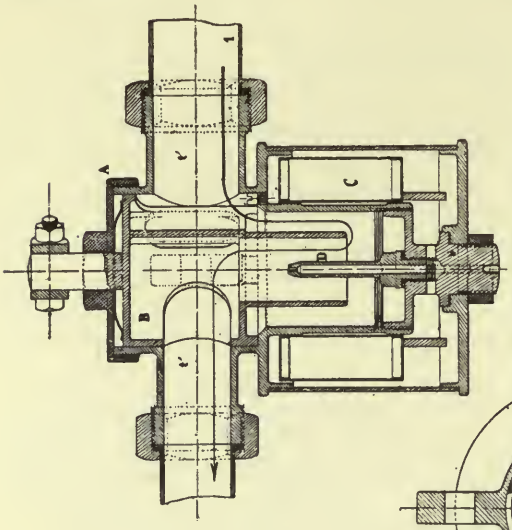


FIG. 81.

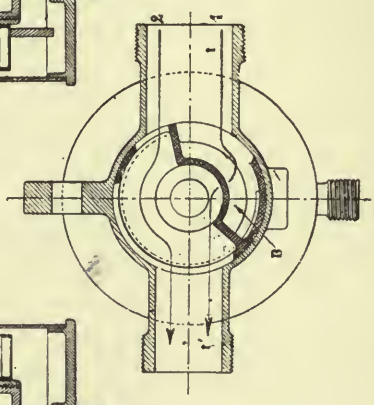


FIG. 80.

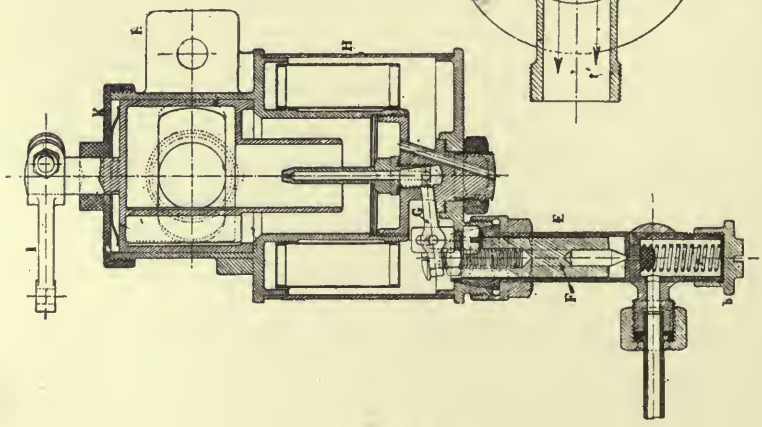


FIG. 79.

De Dion-Bouton Spray Carburretter.

A, Fine gauze sieve.
b, Cap holding *r*.
B, Regulating valve.
C, Float.
D, Spray.
E, Tube enclosing F.
F, Weighted needle valve.
G, Balance lever.
H, Float chamber.
H, Level of petrol.
K, Cap of valve chamber.
L, Lever working regulating valve.
b, Waste cap.
r, Spring carrying gauze sieve A.
t, Air inlet.
t', Mixture outlet.
1, 2, Direction of air.
3, 4, Direction of petrol.

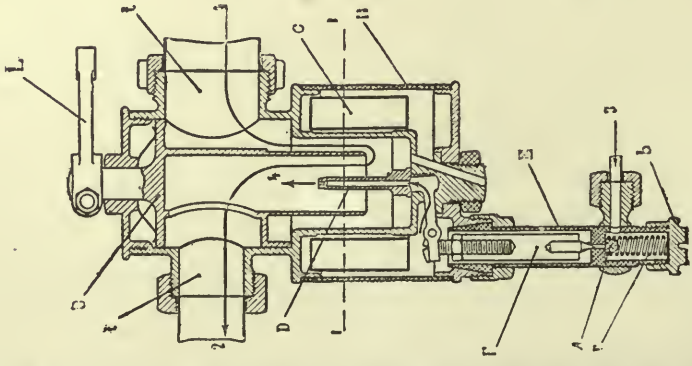


FIG. 78.

The level of the petrol can be regulated when desired by increasing or decreasing the length of F by means of the screw and locking nut provided for the purpose.

The sieve A prevents dirt entering float chamber or spray. Any dirt or water in the petrol is collected in cap B, which can be easily removed and cleared.

To obtain uniform results it is extremely important that the exact level of the petrol in the spray is maintained. In other spray carburetters the spray is outside the float chamber, and the level therefore varies according to the inclination of the car on the road, the differences being very considerable. In this carburetter the level is constant, because the spray is placed right in the centre of the float chamber, the float being made in the form of a hollow ring.

The suction of the motor draws air through passage 1, and this air is deflected over and sucks petrol out of the spray D, vaporises it, and enters the motor through the tube l^1. Air drawn through passage 2 (Fig. 80) does not pass over the spray, but passes direct to the motor, mixing on the way with the petrol vapour from passage 1, and diluting it as required.

As the volume of petrol drawn up at each suction stroke varies with the speed of the motor and the consequent speed at which the air passes over the spray, it is necessary to have some means of regulating the proportions of air passing through passages 1 and 2. This is accomplished by the valve B, which is actuated by the lever L. In the centre of the movement the passage 2 (Fig. 78) is closed, all the air drawn in passing over the spray. Moved in one direction, the opening to the carburetter is reduced, and the suction on the spray thereby increased. Moved in the other direction, the passage 2 (Fig. 78) is opened, and the proportions of air passing through the passages 1 and 2 are varied; the perfect mixture required for any speed of the motor is thus obtained.

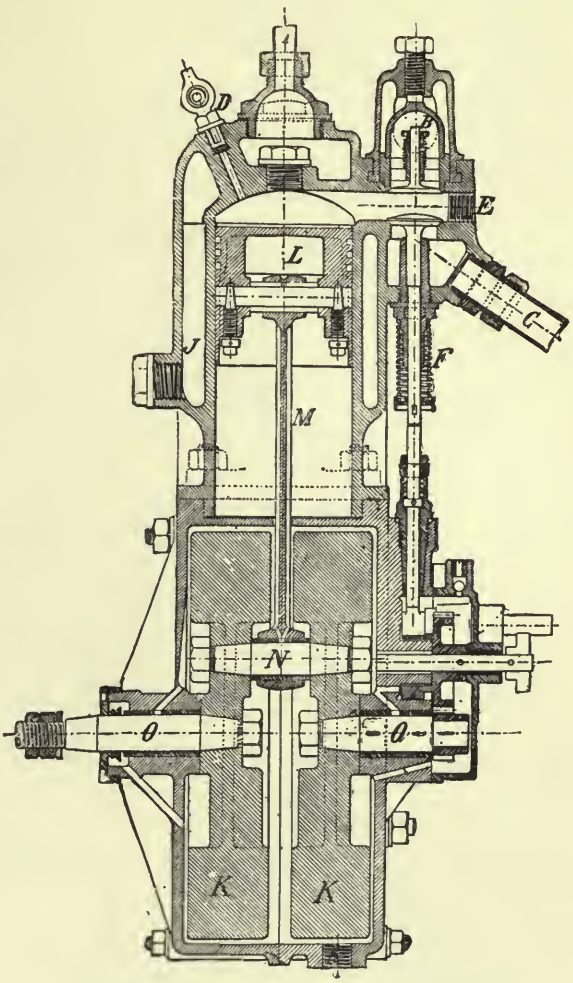


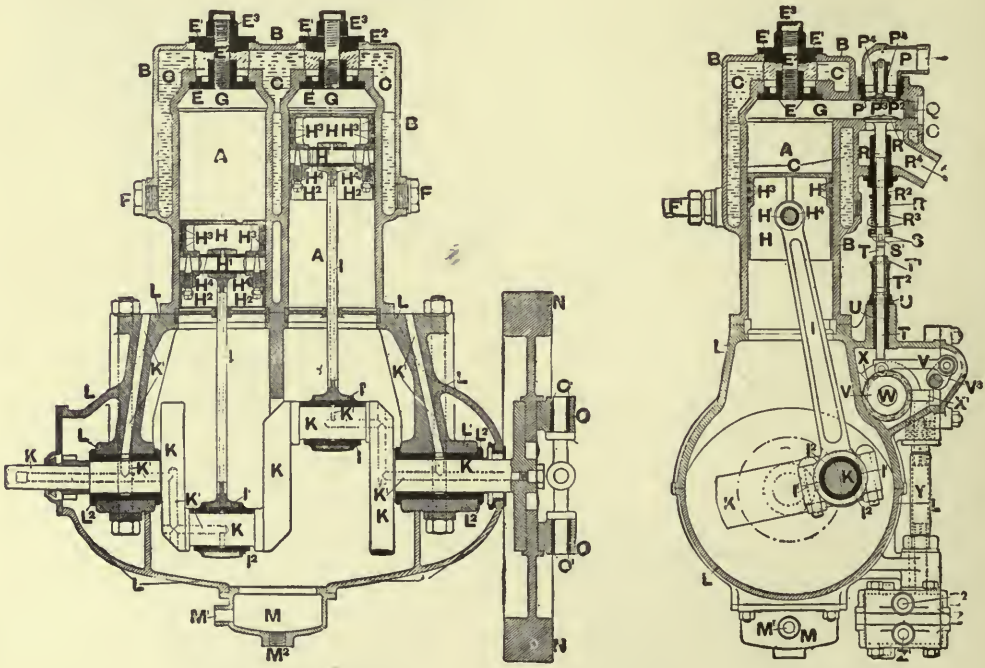
FIG. 82.—De Dion-Bouton Single Cylinder Engine.

Index to sectional view of single cylinder motor (Fig. 82):—

A, Oil outlet.
B, Gas inlet.
C, Exhaust outlet.
D, Compression tap.
E, Sparking plug hole.
F, Spring of exhaust valve.
I, Water outlet.
J, Water-jacket plug.
KK, Fly-wheels.
L, Piston.
M, Connecting rod.
N, Axle connecting fly-wheels.
OO, Motor axles.

Index to section of twin cylinder engines (Fig. 83):—

AA, Cylinders.
BBB, Water jacket.
CCC, Water space.
EE, Lower cylinder caps.
E^1E^1, Outer cylinder caps.
E^2E^2, Studs to cylinder caps.
E^3E^3, Nuts to cylinder caps.
FF, Water-jacket plugs.
F^1, Water inlet.
GG, Cylinder compression spaces.
HH, Pistons.
H^1H^1, Gudgeon pins.
H^2H^2, Set screws for holding gudgeon pins.
H^3H^3, Piston rings.
H^4H^4, Phosphor bronze bush.
II, Connecting rods.
I^1I^1, Big ends.
I^2I^2, Big end bushes.
KKKK, Forged steel crank shaft.
K^1K^1, Oil leads.
LLLL, Aluminium crank chamber.
L^1L^1, Bearings formed in crank chamber.



Sectional Elevation. Cross Section.

FIG. 83.—De Dion-Bouton Twin Cylinder Engine.

$L^2L^2L^2L^2$, Phosphor bronze bushes crank shaft bearings.
M, Oil well of crank chamber.
M^1, Junction for suction pipe to oil pump.
M^2, Wash-out plug.
NN, Fly-wheel.
OO, Engine shaft, half of the universal joint.
O^1O^1, Bushes to universal joint.
P, Induction valve dome.
P^1, Induction valve.
P^2, Induction valve spindle.
P^3P^3, Induction valve spindle guide.
P^4P^4, Induction valve spring.
Q, Sparking plug orifice.
R, Exhaust valve.
R^1R^1, Exhaust valve spindle.
R^2, Exhaust valve spindle guide.
R^3, Exhaust valve spring.
S, Exhaust valve spring cap.
S^1, Cotter securing same.
T, Exhaust valve striking rod.
T^1 and T^2, Cap and spring to same.

UU, Bushed guide to exhaust striking rod.

V, Exhaust valve striking lever varying lift of exhaust valve.

V[1], Exhaust cam.

V[2], Link movement for varying lift of exhaust valve.

W, Half-time shaft.

X, Worm wheel on half-time shaft driving perpendicular pump shaft.

X[1], Worm wheel on pump shaft.

Y, Perpendicular pump shaft.

ZZ, Rotary oil pump.

Z[1], Oil suction pipe.

Z[2], Oil delivery.

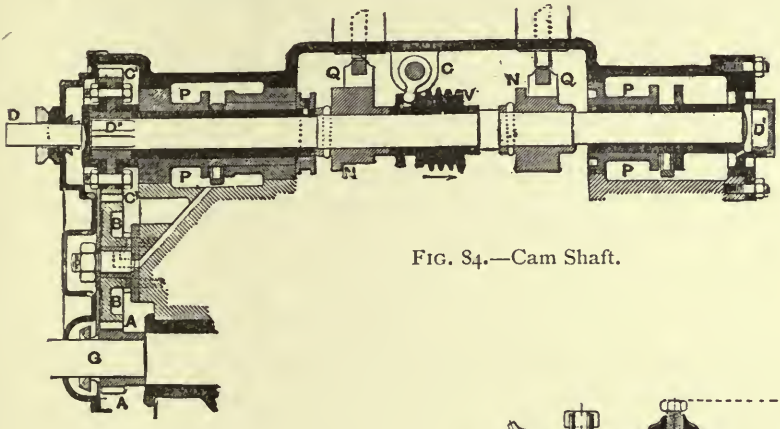


FIG. 84.—Cam Shaft.

Index to cam shaft (Fig. 84):—

AA, Pinion driving half-time gear.

BB, Intermediate pinion.

C, Lever to move sleeve carrying worm driving pump and exhaust valve cams.

C[1]C[1], Pinion on half-time shaft.

D, Extension of half-time shaft to receive contact breaker cam.

D[1], Cap.

D[2], Half-time shaft.

NN, Extra cams to slightly reduce compression on compression stroke to facilitate starting.

PP, Oil wells or ring lubrication of half-time shaft bearings.

QQ, Pieces of exhaust valve regulator under exhaust striking rods. (See V, Fig. 83.)

V, Worm engaging pinion of pump shaft.

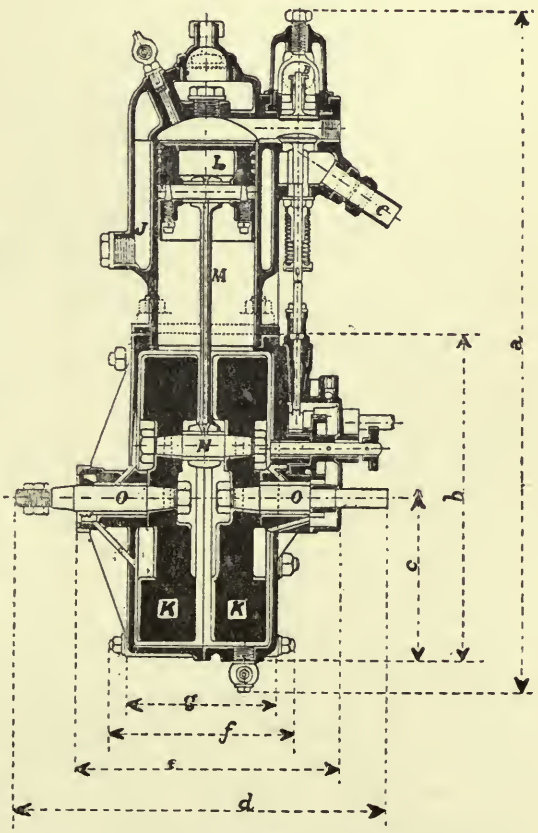


FIG. 85.—Dimensions of De Dion-Bouton Engines.

Referring to Fig. 85, the following table gives the approximate dimensions of the De Dion motors :—

TABLE I.

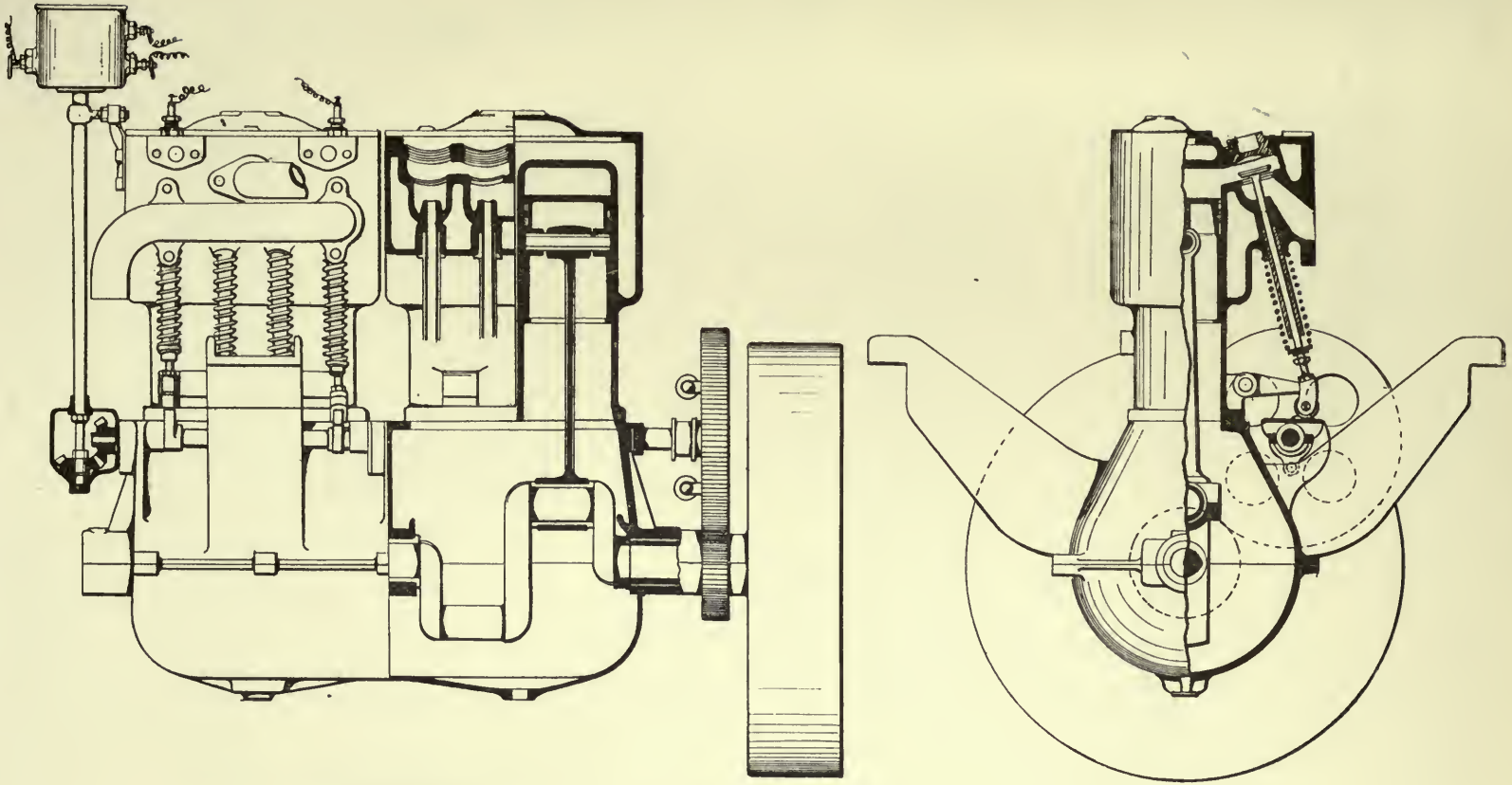
	Millimetres.					Inches.				
Horse-Power.	4½	6	8	10	12	4½	6	8	10	12
a	600	660	723	660	660	23⅝	26	28½	26	26
b	280	305	330	340	340	11	12	13	13⅜	13⅜
c	140	153	170	175	175	5½	6	6¾	6⅞	6⅞
d	330	380	415	565	565	13	15	16 5/16	22¼	22¼
e	225	265	300	475	475	8⅞	10½	11 13/16	18¾	18¾
f	158	170	195	...	...	6¼	6¾	7¾	...	...
g	132	144	164	...	...	5 3/16	5 11/16	6 5/16	...	...

THE DAIMLER MOTOR AND CAR

This is another historical name in the petrol engine progress. The latest developments of this engine are shown in Fig. 86; accessibility is the leading feature. The cam shaft is outside of the casing, and all visible. The clutch is of fly-wheel type, and is shown separately in Fig. 87. The speed gearing is shown in Fig. 88.

The 4-cylinder engine is of the slow-running type. It has a bore of 110 millimetres, and a piston stroke of 150 millimetres, while at 750 revolutions per minute it develops 28 brake horse-power. It can be readily accelerated to 1000 revolutions per minute, and under these conditions gives 36 brake horse-power. Both induction and exhaust valves are mechanically operated, and are placed on the same side of the engine. The carburetter and throttle is of entirely new design, giving a positive regulation of mixture at all loads and speeds of the motor, and combined with it is a gradual throttle, which is actuated by an automatic governor, and by a master hand control. The ignition used is the high-tension system, employing only one coil and trembler, and one low-tension timing brush. Distribution is effected in the high-tension circuit, the distributor itself being placed on a vertical spindle, in a most accessible position above the engine. The results secured by this system are simplicity of wiring, extremely accurate timing, and great reliability. It is interesting to note that the magneto high-tension system can readily be attached to the engine if desired, and this, too, not in an experimental form, but fitted in a manner which prolonged trials have proved to be absolutely satisfactory. The water-cooling system of previous Daimler types has been very considerably modified, for the usual tank has been entirely dispensed with, and a belt-driven fan fitted behind the radiator. It may be noted that the radiator, pump, and engine water jackets are located closely together, and connected by short and direct pipes, thus ensuring free circulation and effective cooling, and at the same time minimising the possibility of leakage or deterioration. The lubrication of the engine is ensured by a three-sight pressure-feed lubricator placed upon the dashboard, and by an ingenious arrangement this is automatically replenished from the main oil reservoir when required. The copper petrol tank is, as in former types, placed in the rear of the chassis, and has a capacity of 16 gallons.

The power is transmitted to the road wheels by the usual system of friction clutch, cog gear, and chains. The first-named is somewhat remarkable by reason of the light-



Sectional Elevation.

Sectional End View.

FIG. 86.—Diamler 4-Cylinder Engine.

ness of the leather-covered cone, and the extremely easy method of adjustment adopted. Moreover, the foot pedal which actuates it is particularly easy of manipulation, an advantage which lady drivers in particular will appreciate.

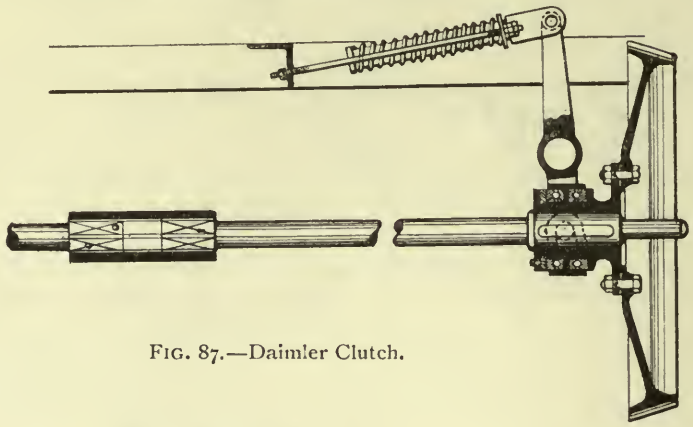


FIG. 87.—Daimler Clutch.

The gear case and transmission gear does not present any strikingly new features, but it may be noted that the case itself is so suspended as to permit of self-alignment. The bearings are fitted with automatic ring lubrication, and the gears are made of case-hardened steel.

It is not to be wondered at that the company has made no alteration in its system

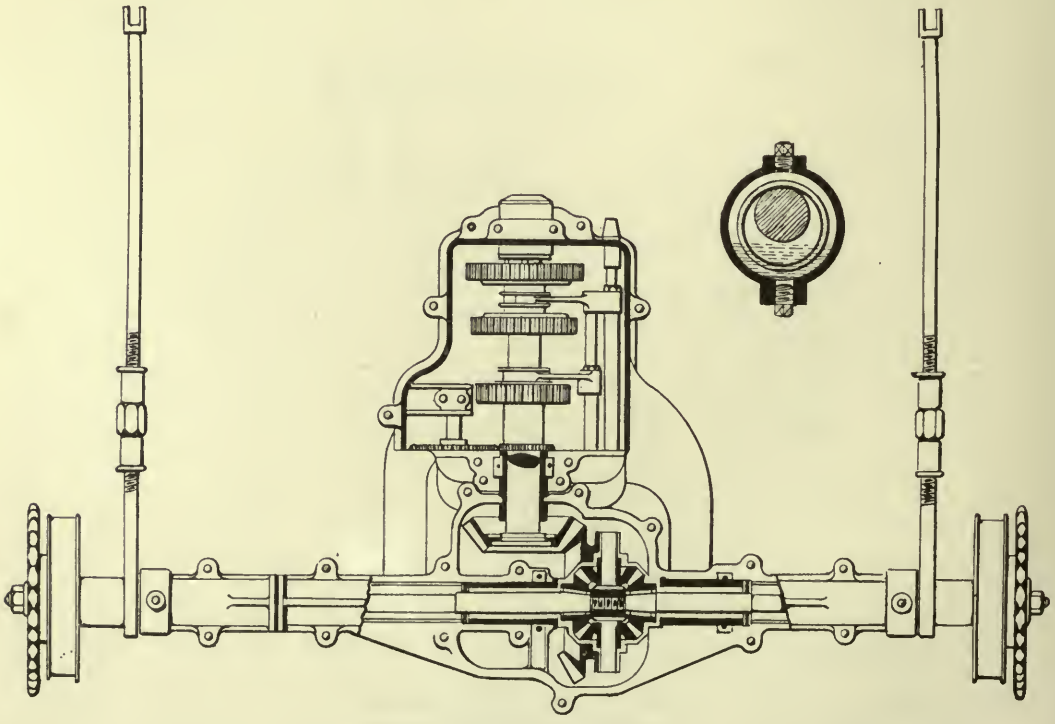


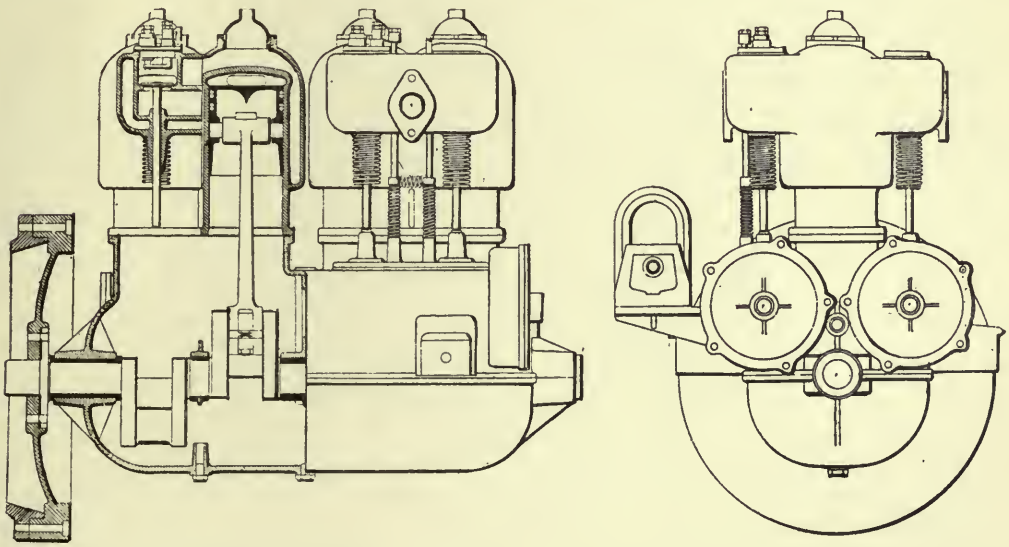
FIG. 88.—Daimler Speed Gear.

of speed change control, for this nearly approaches perfection. Each change of speed is effected by a full and positive stroke of a single lever, and the driver is not called upon to feel or look for notches, as in the case of other system.

THE BROOKE AUTOCAR

Reference has already been made to the Brooke carburetter and governor, and the engine is well seen in Fig. 89 and Plate II. The general design of the cylinders—which are cast in pairs—and of the crank chamber—which also encloses the gear wheels driving the cam shafts—is shown in Fig. 89. The cylinders have a bore of 94 millimetres, and the stroke is 115 millimetres ; at the normal of 900 revolutions per minute the engine develops about 20 brake horse-power and at a speed of 1500 revolutions per minute about 25 brake horse-power. The engine is in practice entirely controlled by two hand levers, placed above the steering wheel, the one regulating the time of ignition and the other varying the speed at which the suction governor comes into operation.

The inlet valves are on the right, the exhaust valves on the left, low-tension igniters form the inspection covers above the former, and high-tension ignition plugs are screwed into the covers above the latter ; separate cam shafts are, of course, fitted for the inlet



Sectional Elevation. End View.

FIG. 89.—Brooke 4-Cylinder Engine.

and exhaust valves. The low-tension igniters are operated by cams on the inlet cam shaft, and the vertical rock shafts through which the igniters are actuated pass through the cylinder castings, thus protecting them from injury and securing compactness. The rocking arm of the low-tension igniters has a large flat surface for the projection on the vertical rock shaft to engage with. This is provided so that the vertical shaft shall continue to engage with it although moved longitudinally up or down. The time of ignition is varied by this movement, because the ignition cams are then made to actuate the rock shafts sooner or later as may be desired in the cycle of operations. This timing device is connected with the upper of the two small hand levers which are fitted above the steering wheel. Simultaneously with timing the low-tension ignition system, the high-tension system is also timed, for there is a connection between the levers that lift the vertical rock shafts and the commutator—which is mounted in front of the dash beneath the bonnet (see Plate II.). This commutator is driven by a chain off the rear end of the inlet cam shaft, and is used in conjunction with trembler coils, fixed behind the dash, and the usual battery of accumulators.

The magneto shown in Plate II., which is of the Simms-Bosch type, and runs at

half the speed of the crank shaft, is placed to the right of the engine, and is driven by exposed spur wheels—one of which is made of fibre and phosphor bronze—from the front end of the inlet cam shaft. The insulating wire from it is led to a distributing plug fitting, and the four wires to the igniters terminate in plugs that fit into its sockets. The length of the wires is in this way kept short, and they are not only easily disconnected for testing purposes, but are unlikely to get in the way. The high-tension wires on the other side of the engine are similarly protected. Both ignition systems are controlled by neat metal-cased switches, which are fixed to the steering pillar, so that the driver can cut out either or both systems without moving from the seat.

There are large water jackets around the cylinders, the cylinder heads, and the valve chambers. The water is forced into the bottom of the jacket in each casting by a pump of the gear-wheel type, which lies to the left of the engine in front, and is driven from the front end of the exhaust cam shaft. The water is led out at the top of the jackets above each of the four cylinders, and passes direct back to the top of the honeycomb radiator by a short branched pipe. The belt-driven fan behind the

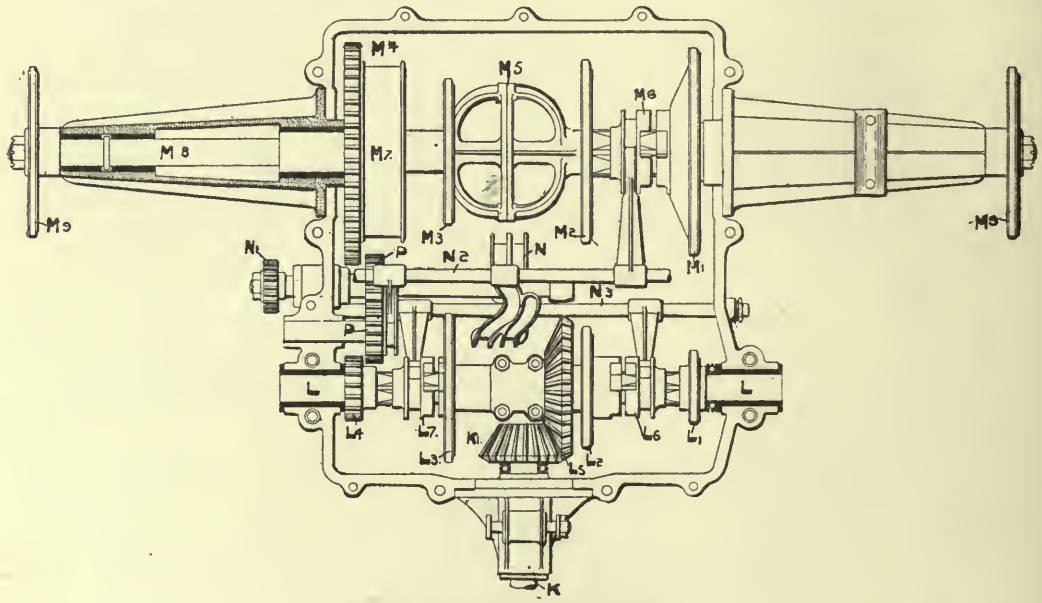


FIG. 90.—Brooke Speed Gear.

radiator is mounted in bearings which are attached to it, the rear end of its spindle being supported by three tubular stays. A wide, flat belt drives the fan from a pulley on the crank shaft, and, as we have already said, the fly-wheel also acts as an additional fan to assist in creating a draught through the radiator.

The engine is fed with oil from a sight-feed lubricator on the dash, and a pressure is maintained in this lubricator by the exhaust gases in much the usual way, through a valve fitting. The lubricator also has a hand pump for forcing oil to the crank chamber, and a pressure gauge is fixed to indicate the pressure in the system. The same pressure valve maintains a pressure in the petrol tank, which has a capacity of about 9 gallons, and is fixed at the back beneath the frame.

The gear box of the Brooke car is shown in Fig. 90 in horizontal section. The short shaft K, which is connected with the clutch by a universal joint, carries the bevel wheel K_1 at its rear end inside the gear box, and this meshes with a corresponding bevel wheel L_5 on the first-motion shaft L. The box itself is made in two pieces parting through the bearings. The second-motion shaft is also the differential counter shaft, and its differential ends pass through separate castings that are bolted on either

side of the main box. The entire gear is fixed to the chassis at three points only—to the longitudinal members of the main frame, immediately above the counter shaft, and to the transverse member of the frame centrally. Mounted upon the first-motion shaft L are three sprocket wheels L_1, L_2, and L_3, and a spur wheel L_4. The wheels L_1 and L_4 are fixed securely to the shaft, but the other two wheels ride freely upon it. Sliding jaw clutch members L_6 and L_7 are also carried upon squares formed on the shaft, and it is by these jaw clutches that either of the wheels L_2 or L_3 can be rendered rigid with it; these two jaw clutches are controlled by forks projecting from a sliding rod N_3. The counter shaft has the differential gear M_5 arranged centrally, and to its shell are firmly fixed the sprocket wheels M_2 and M_3, from which chains pass to the wheels L_2 and L_3 respectively. The sprocket wheel M_1 and the spur wheel M_4 are also mounted upon the sleeve of the differential shell, but the sprocket M_1 is normally free to revolve upon it, and a jaw clutch M_6 is fitted in connection with it. A third chain connects together the two sprockets L_1 and M_1, and the jaw clutch M_6 is controlled by a fork projecting from a second sliding rod N_2. The spur wheel M_4, as also the brake drum M_7, are both securely fixed to the shell of the differential, and there are a pair of intermeshing intermediate spur wheels P, arranged so that they can be slid into engagement with the wheels L_4 and M_4. The first speed is obtained by causing the jaw clutch M_6 to come into engagement, the power then being transmitted through the chain from the wheel L_1 to the wheel M_1. The second speed is introduced by the jaw clutch L_6, the wheel L_2 then driving the wheel M_2 by their chain. The third speed is brought into use by the jaw clutch L_7, the differential gear being then driven by the chain connecting the wheel L_3 with the wheel M_3. The reverse gear results from the introduction of the two intermediate spur wheels P between the wheels L_4 and M_4, and these are slid into engagement by a fork projecting from the sliding rod N_2.

One of the intermediate wheels P is mounted on a short stationary pin, and the other rides upon the shaft, upon the outer end of which carries the spur wheel N_1, seen (outside the gear box) in Fig. 90. It is by this shaft that the change speed gear is operated, the wheel N_1 being engaged by a toothed quadrant which is fixed to the change-speed lever, beside the driver. Inside the gear box the shaft carries a specially shaped cam N, the grooves in which engage with pins projecting on the two sliding rods N_2 and N_3. The shape of the cam grooves is such that the various gears are introduced consecutively. The hand lever on the side of the car is so arranged that it is drawn back towards the driver—instead of being pushed forward—to introduce the higher gears. The quadrant is so notched that the lever can be pushed forward without disengaging the catch, but that the catch holds it in either working position, and prevents it from being drawn backward until withdrawn. The two differential shafts M_8 and the short driving shaft K are provided with ring-lubricated bearings, and it will be noticed that plain bearings are used throughout, although ball-thrust bearings are introduced behind the bevel K_1 and L_5. The power is transmitted from this change-speed gear to the rear wheels by side chains from the sprockets M_9.

THE ARGYLL CAR ENGINE AND GEAR

In this car we may find the engine and its gearing of interest, as made by the Hozier Company.

The left-hand side of the engine is shown in section through the centre of the cylinder, and a cross section in Fig. 91. The piston D is of ample depth, and four piston rings are provided, the bottom ring holding the wrist pin in position, dispensing with the use of any small screws which are liable to get loose. The water jacket is of good capacity, as can be seen on line drawing. The connecting rod E is machined from steel stamping, and the crank shaft B is made from

a high quality of nickel steel, the balance weights being solid with the crank shaft. It will also be seen that there is a bearing between each crank, and these bearings are the same size, and interchangeable with the connecting rod end bearings. The centre portion of the engine is shown in section through the centre of the valves; the valves are all alike and interchangeable. M is the inlet valve, and N is the exhaust valve. They are both mechanically operated by the cam shaft H, which is driven by the two-to-one gear G. The valve lifters are marked W, and they are all provided with anti-friction pulleys L. The lifts of the valves can be adjusted by the pin and locknut U. The outside view of the engine is shown on the right-hand side, O being the inlet pipe and P the exhaust pipe. They are held to the cylinder heads by means of dogs, and are quickly and easily detached. A large diameter fly-wheel F is provided. Inspection doors are fitted at both sides and bottom of crank chamber marked R. The engine is suspended direct to the main frame X. It is lubricated on the splash system, and the bearings are provided with oil pockets, ensuring the proper distribution of the lubricant.

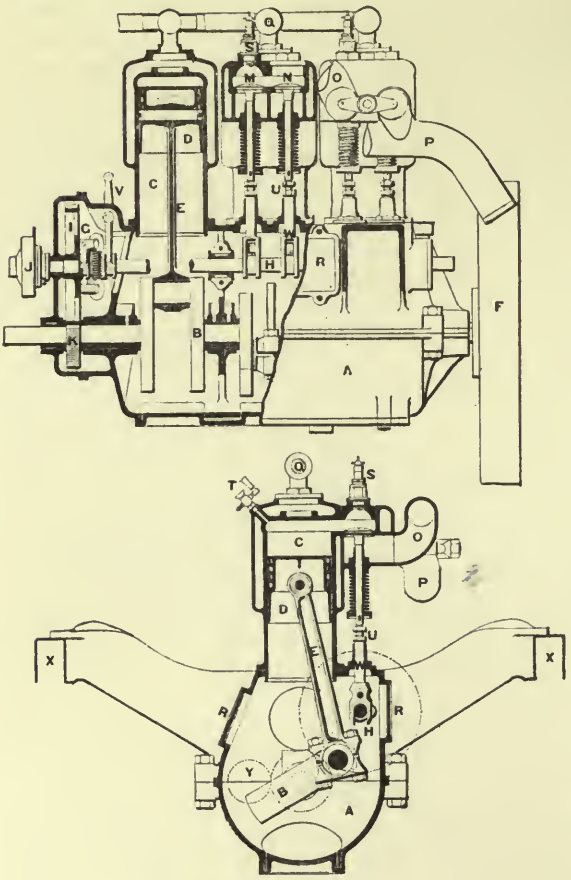


FIG. 91.—Argyll Engine.

A, Crank chamber.
B, Crank shaft.
C, Cylinders.
D, Pistons.
E, Piston rods.
F, Fly-wheel.
G, Governor.
H, Cam shaft.
I, Cam shaft half-speed wheel.
J, Commutator.
K, Half-speed pinion on main shaft.
L, Rollers for cam.
M, Inlet valve.
N, Exhaust pipe.
O, Inlet pipe.
P, Exhaust pipe.
Q, Water unions.
R, Inspection door.
S, Sparking plug.
T, Compression tap.
U, Adjusting pins for valves.
V, Governor controlling lever.
W, Valve lifter.
X, Frame.
Y, Pump driving wheel.

The clutch is shown in Fig. 92. A is the engine shaft carrying the flange D, to which is bolted the fly-wheel E. The internal portion of the friction clutch G is mounted on an engine shaft C, C being a hardened steel bush in which the engine shaft runs when the foot pedal is depressed. F is a conical ring which forms the external portion of the clutch, and is held in the fly-wheel by means of the bolts B, there being three of these bolts in the circumference. Any wear of the leather can thus be immediately

taken up by drawing the conical ring F farther into the fly-wheel by means of the bolts B. I shows the leather covering of the internal portion of the clutch G, and the spring is shown at L. The clutch is self-contained, and as it all turns together no end thrust can be transmitted to any bearing, unless when the foot pedal is depressed, bringing the thrust ball bearing K into action, loss of power only taking place when the car is being stopped. A hardened steel grooved part M is bolted to the internal portion of the clutch G, which prevents wear from the action of the levers which operate the clutch. A lubricator is mounted on J for supplying oil to the bearings.

The clutch can never get out of alignment, as all parts are mounted concentrically on the engine shaft. By unscrewing the bolts B the conical ring F can immediately be withdrawn for cleaning, and any required adjustment can immediately be made. As the leather wears the clutch is self-adjusted.

Index to Fig. 92:—

A, Engine shaft.
B, Friction clutch adjusting pin.
C, Engine shaft bush.
D, Engine shaft flange.
E, Engine fly-wheel.
F, Conical ring.
G, Friction clutch.
H, Friction clutch coupling.
I, Friction clutch leather.
J, Lubricator.
K, Ball race.
L, Spring.
M, Hardened steel grooved sleeve or coupling.

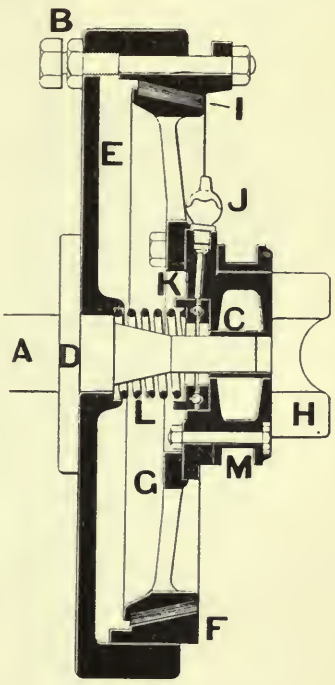


FIG. 92.—Argyll Clutch.

Power is transmitted from the engine through the friction clutch to the fork A (Fig. 93), which is firmly fixed to the hollow shaft on which the pinion E is cut from the solid; the power is then transmitted to the propeller shaft by means of the shaft B, which is turned down at one end to run in the hollow shaft. The direct top speed drive is obtained by sliding the piece F, which is mounted on the square part of the shaft B until the clutch K^1 engages with the clutch K. The shaft B will now be rotated at the same speed as the shaft E, and the pinions H, J, and G will run idle. It will be observed that the clutch K^3 will revolve at a slower speed than the clutch K, according to the ratio of the pinions E, H, and JG, so that when the piece F is moved until the clutch K^2 engages with K^3 then the second speed is obtained. To secure the first speed the pinion F is put back in the mid position, and the pinion I is moved on the square counter shaft C until it engages with the pinion F. The pinion A^1 is mounted eccentrically in the lid of the gear box, and is broad enough to engage with the slow-speed pinions IF when they are not in mesh. In this way the reverse is obtained. The various movements are explained by referring to line drawings. The sliding pinions F and I are operated by levers O and M respectively.

Figs. 94 and 95 show the action of the change-speed lever. The quadrant is shown at S (Fig. 94), and the change-speed lever is marked X. When the lever X is in the central position, midway between the first, second, and third speeds (see Fig. 95), then the gear box is in the free position. When the change-speed lever X is moved backward and forward between the second and third speeds, then there is no motion given to the slow-speed actuating bell crank M; and when the hand lever X is pushed into the first-speed position in the quadrant, then there is no motion given to the

second and third speeds operating lever O, so that the second and third speed actuating fork L would remain in the free wheel position when the first speed is engaged. Second and third speeds are operated through the rocking shaft T, the lever P, the lever O, the sliding joint Q, and the shaft R, to which is fixed the actuating fork L, which is pulled backward and forward in the gear box when the hand lever X is operated in the second and third speeds.

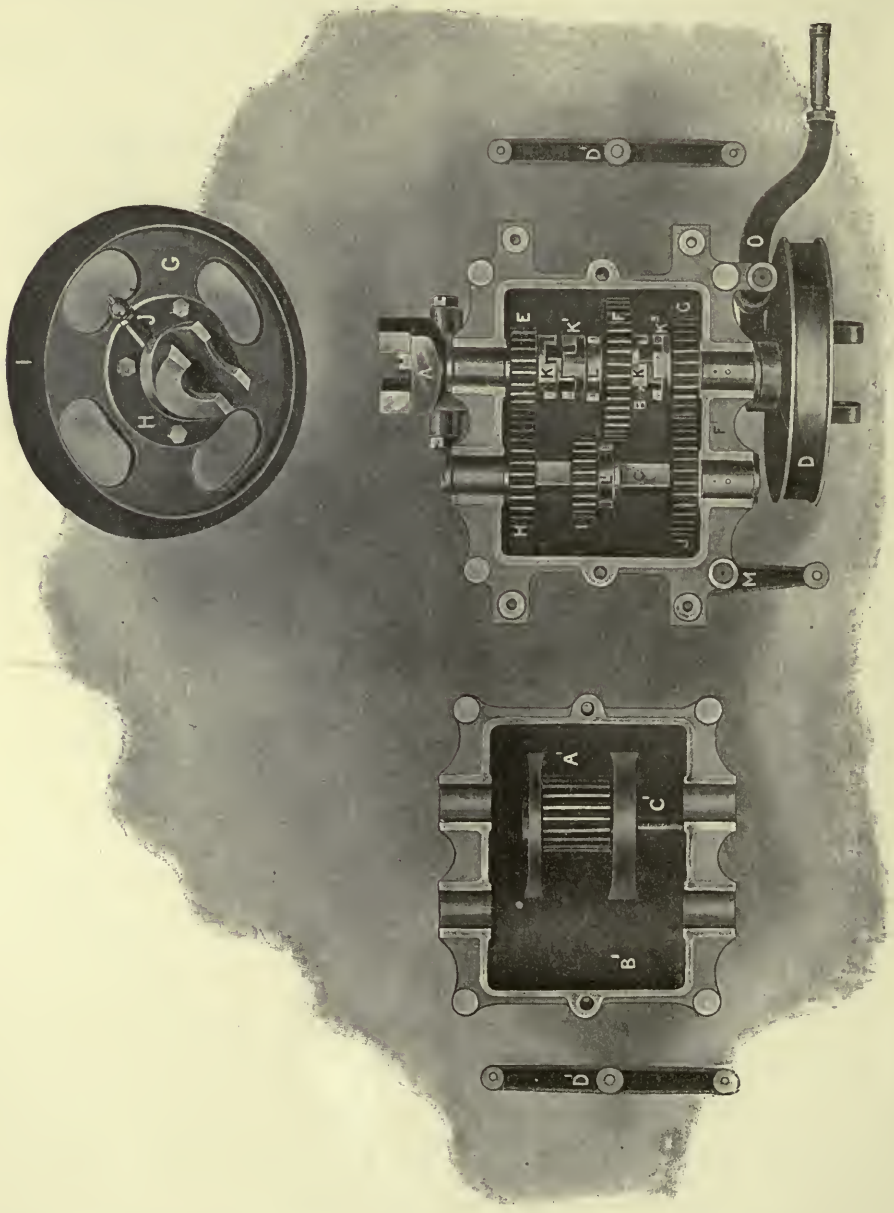


Fig. 93.—Argyll Speed Gear and Clutch

A, Sliding coupling.
B, Main shaft.
C, Counter shaft.
D, Brake drum.
E, 3rd-speed pinion.
F, 1st-speed wheel.
G, 2nd-speed wheel.
H, Counter shaft speed wheel.
I, 1st-speed pinion.
J, 2nd-speed pinion.

K, 3rd-speed clutches.
K_1 3rd-speed engaging clutches.
K_2 2nd-speed engaging clutches.
K_3 2nd-speed clutches.
L, Actuating fork (main shaft).
L_1 Actuating fork (counter shaft).
M, 1st-speed bell crank.
O, 2nd and 3rd-speed bell crank.

A_1 Reversing pinion.
B_1 Gear box cover.
C_1 Reversing spindle.
D_1 Gear box cover clamps.
F_1 Gear box.
G, Aluminium friction clutch.
H, Friction clutch coupling.
I, Friction clutch leather.
J, Lubricator for ball race and spindle.

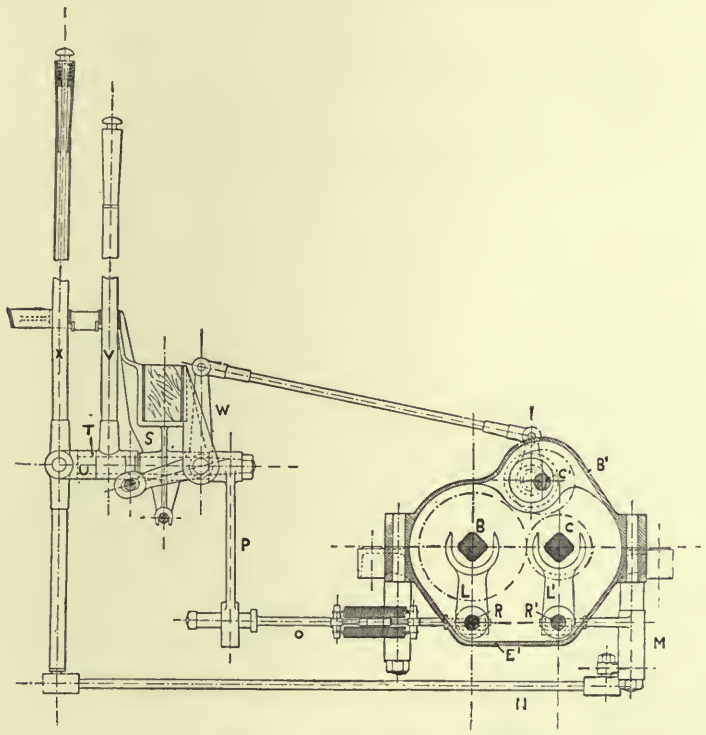


FIG. 94.—Sectional Elevation of Gear.

Index to Figs. 94 and 95:—

B, Main shaft.
C, Counter shaft.
D, Brake drum.
L, Actuating fork (main shaft).
L_1, Actuating fork (counter shaft).
M, 1st-speed bell crank.
N, 1st-speed connecting rod.
O, 2nd and 3rd-speed bell crank.
P, 2nd and 3rd-speed connecting lever.
Q, Sliding pivot.
R, Actuating shaft (main).
R_1, Actuating shaft (counter).
S, Quadrant.
T, Rocking shaft.
U, Rocking shaft fork.
V, Reversing lever.
W, Reversing bell crank.
X, 1st, 2nd, and 3rd-change-speed lever.
Y, Frame.

The first speed is operated through the connecting rod N, the bell crank M, and the sliding joint Q^1, which pulls the shaft R^1, to which is fixed the slow-speed actuating fork L_1, through the gear box, and in this way engaging the first speed. An enlargement of

the lever O is shown at Fig. 95. The main fulcrum is at *e*, and when there is no resistance the lever O acts as if it were pivoted about the fulcrum E; but should the change-speed lever X be forced at the wrong time, then the spring C would stretch and prevent any damage being done to the clutches of the gearing. It will be observed that the little levers *b* are pulled against the stops *d* by means of the springs *c*, so that the point Q will always return to its normal position. This improvement removes almost all danger of breaking gears.

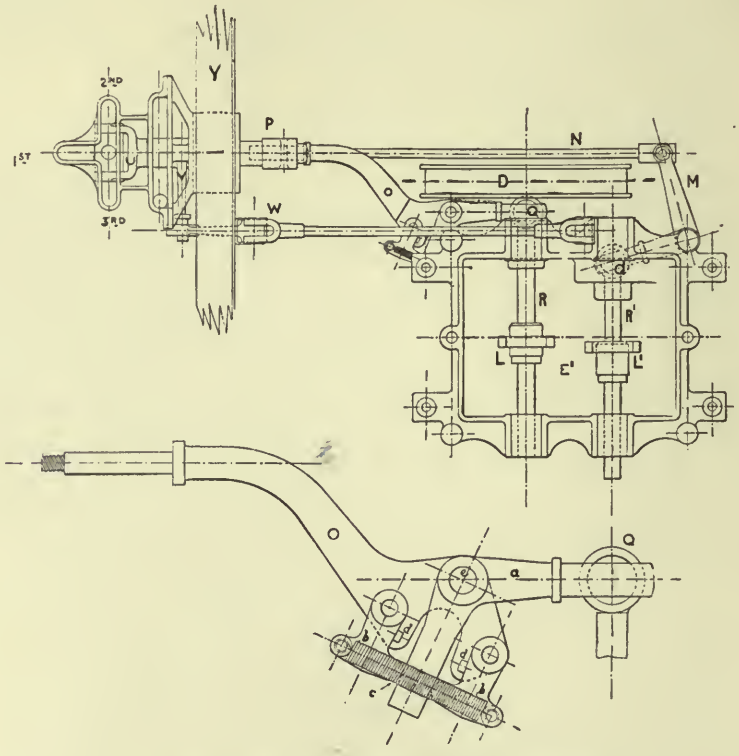


FIG. 95.—Plan of Gear and Enlarged View of Flexible Lever.

Index to lower portion (Fig. 95):—

O, 2nd and 3rd speed bell crank.
Q, Sliding pivot.
a, Actuating bell crank.
b, Spring links.
c, Spring.
d, Spring link stops.

A separate hand lever V operates the reverse through the bell crank W and the connecting rod which is fixed to the end of the small lever which is fixed to the eccentric stud C^1. The reverse pinion is mounted on the eccentric stud C^1, and when the operating lever V is pulled to the opposite end of the slot in the quadrant, the reverse gear wheel is introduced between the slow-speed pinions when the forward gear operating lever X is in the central position of the quadrant.

The points claimed for the improved gear are:—When driving at night there is no chance of missing the gears, as the change-gear lever is in each direction pushed to a full stop, there being no slots to find in the quadrant. It is also impossible to put in the reverse gear in the dark, as it is operated by a separate lever. Owing to the levers O being made flexible it is impossible to smash the clutches or strain the gear. The gear shafts are short, obviating all spring. The teeth are perfectly cut, and the gear runs noiselessly. The gear is most accessible; it can be taken out of the car in a few minutes.

THE MOTOR CYCLE

Hitherto we have confined our attentions to the larger types of petrol cars ; smaller motors are used to some extent for propelling bicycles and tricycles. A good example is that cycle motor constructed by the "Ariel" Cycle Company, which is here taken as an example of the class.

We will first describe the engine, a sectional view of which is given in Fig. 96. As being the propelling power, it is the most important member of any motor vehicle. The special features of the engine are high speed, capable of running from 250 to 3000 revolutions per minute, thus giving great flexibility, with a large range of various speeds ; 2 × 1 gear operated by spiral worm drive, ensuring narrow tread ; extra large bearings ; automatic lubrication of all engine parts and detachability without disturbing crank case, mechanically operated valves, inlet and exhaust valves interchangeable ; extra large seats, thus lessening extent of lift. Fly-wheels in two halves, each solid forged steel and of equal weight. Phosphor bronze bearings throughout. A very important point in the general construction is that each of the chief elements, such as crank case, two-to-one gear, contact breaker, etc. etc., are self-contained.

The cylinder and cylinder head are provided with especially large radiating surfaces.

Both valves are fitted behind the engine, which is the most suitable position, as it admits of the exhaust gases being taken in their proper direction, *i.e.* away from the engines ; and further, being in this position, they are not shielded by the front mudguard from obtaining maximum cooling.

A, Cylinder.
B, Crank case.
C, Screwed cylinder head.
D, Inlet valve cap.
E, Exhaust valve cap.
F, Connecting rod.
G, Left-hand half fly-wheel.
H, Gudgeon pin.
I, Cam shaft.
J, Inlet valve lifter.
J^1, Exhaust valve lifter.
K, Inlet valve tappet rod.
K^1, Exhaust valve tappet rod.
L, Exhaust valve.
M, Inlet valve.
N, Inlet guide.
O, Exhaust valve guide.
P, Paraffin tap.

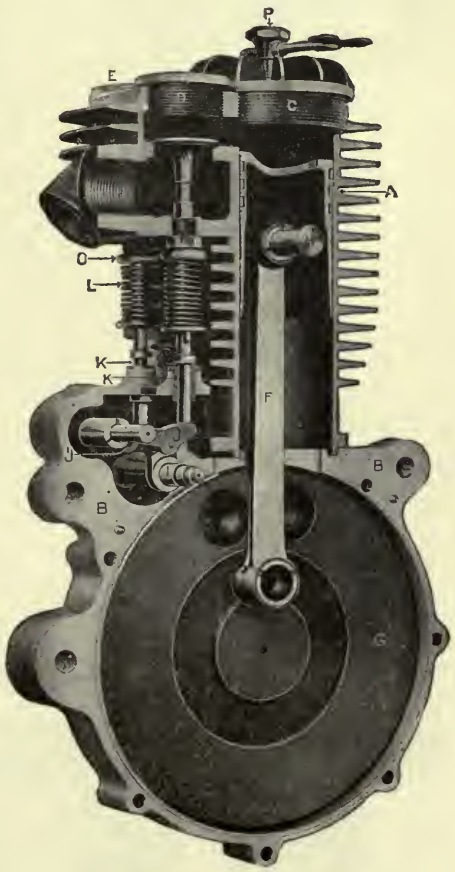


FIG. 96.—Auto-Cycle Engine.

One of the chief and original features of the $2\frac{3}{4}$ and $3\frac{1}{2}$ horse-power engine is the method of operating the 2 × 1 gear as illustrated in Fig. 97. By means of worm gear and spiral shaft the inlet and exhaust valve lifting gear is entirely self-contained, and can be removed, examined, or adjusted without disturbing the crank case. Ball-thrust bearings are fitted to each end of the shaft, the gears are cut right and left, so that end thrust is obviated. The action of the spiral gear shaft when the engine is running is as a screw propeller to the

oil, thus ensuring a continuous flow of oil from the crank case to all the working parts of the engine. The oil is thrown out of the crank case by centrifugal force of the fly-wheels through two small holes into the cam chamber, oiling the cams, valves, levers, and tappets. It then runs out of the crank chamber through a hole in the case leading into the spiral gear case, first oiling the top gear, then running down by gravitation to the second, thence by the action of the spiral gear cut upon the crank axle it is returned to the crank case, and the cycle of operations repeated over and over again.

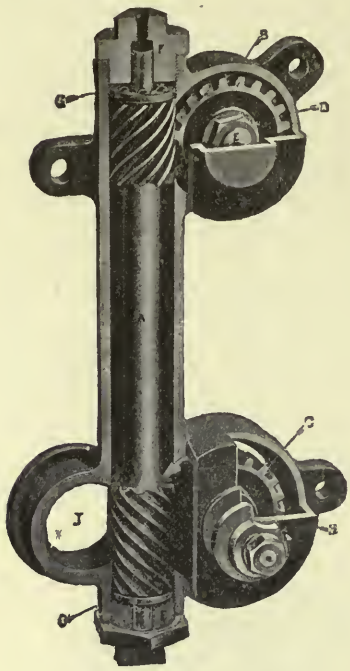


FIG. 97.—Spiral Worm Gear.

Index to spiral gear :—

A, Spiral worm shaft for operating 2 × 1 gear.
B, Phosphor bronze cover for 2 × 1 gear.
C, Sparking cam gear.
D, Valve cam gear.
E, Valve cam shaft.
F, Step-bearing for spiral shaft.
G, Ball-thrust bearings.
H, Contact breaker cam.
I, Crank shaft hole.
J, Adjusting nut.

The method of fixing the connecting rod to the fly-wheels is another important feature. In addition to the connecting rod being held by the crank pin sleeve illustrated in Fig. 98, the rod is finally fixed to the fly-wheels by means of a substantial bolt.

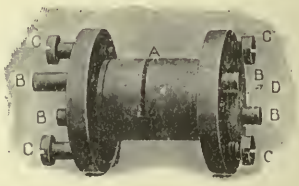


FIG. 98.—Crank Pin Sleeve.

A, Sleeves in two halves.
B, Dowel pins for preventing rotary movement.
C, Locking screws.
D, Hole for crank pin.

The fly-wheels (Fig. 99) are each made of solid forged steel, all working parts hardened and ground. The engine is perfectly balanced, as owing to special method of building up connecting rod it is impossible for the fly-wheels to get out of alignment.

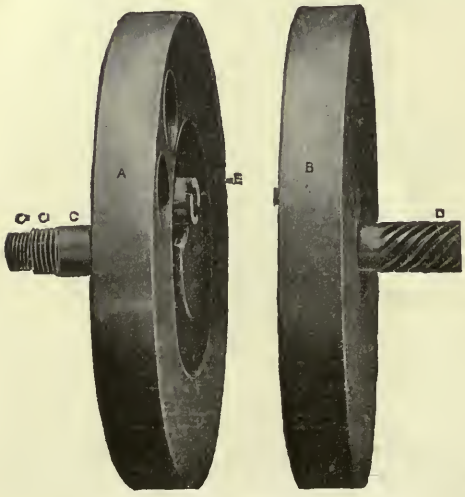


FIG. 99.—Fly-wheels.

A, Left-hand half fly-wheel.
B, Right-hand fly-wheel.
C, Crank shaft.
C^1, Screw for pulley.
C^2, Screw for pulley lock nut.
D, Crank shaft showing worm gear.
E, Crank pin sleeve.
F, Bolt for fixing crank pin sleeve upon which connecting rod is carried.

The piston is fitted without the use of loose emery or other loose grinding materials. The piston and rings are ground true in their places,

which therefore obviates any distortion which may be caused by springing the rings on to the piston.

The bearings are pressed into the crank case, and in addition are secured by a key and bound endways by a lock nut, thus precluding the possibility of their coming loose or turning round in the case. Oil channels are cut as shown in illustration (Fig. 101).

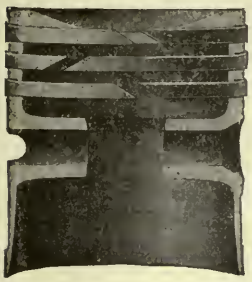


FIG. 100.—Piston.

A, Phosphor bronze bearing.
B, Oil channels.
C, Screw, locking bearing to crank case.
D, Lock nut holding bearing securely in proper position.

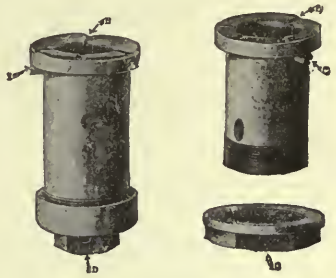


FIG. 101.—Crank Shaft Bearings.

The method of ignition is high tension with positive make-and-break and no trembler coil, the current being supplied by accumulators of the best possible quality.

The contact breaker fitted to the $2\frac{3}{4}$ and $3\frac{1}{2}$ horse-power models, as illustrated in Fig. 102, is of novel and distinctive construction. The special features are transparent celluloid face, enabling spark being visible without removing cover; contact screw, adjustable from outside; contact breaker, detachable by undoing two screws and without removing sparking cam, etc. The make, *i.e.* the period during which the circuit is complete, is of sufficiently long duration to enable the coil to perform its office and transpose the primary current into an induced or high-tension current. The break is instantaneous,—this important feature must be appreciated by every student of electricity, as it is a well-known fact that the quicker the break the fatter the spark at the plug.

A, Contact breaker case.
B, Sparking lever.
C, Sparking lever fulcrum screw.
D, Plunger for lever.
E, Plunger spring.
E,[1] Plunger spring cap.
F, Tension screw.
G and G[1], Swivel bush in two halves.
H and H[1], Screws for swivel bush.
I, Contact screw.
J and J[1], Locknuts for contact screw.
K, Guide for contact screw.
L, Insulated fibre bush.
M, Stop screw.
O, Cam.

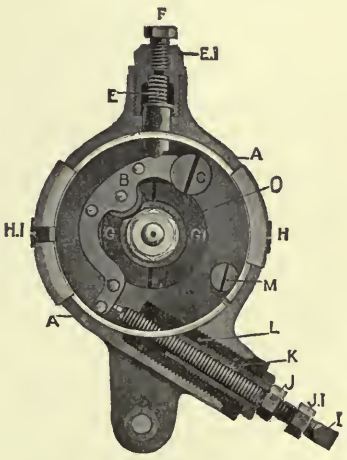


FIG. 102.—Contact Breaker.

In the past, when it was customary to fit engines to motor cycles varying from 1 to 2 horse-power, the surface type of carburetter has been much used; but with the advent of more powerful engines a spray and float feed type is to be recommended, as the surface, with a sufficiently large carburetting capacity to furnish the extra fuel required for the powerful engines now in demand, gives an unsightly appearance to the machine, and in addition monopolises valuable space.

The accompanying illustration (Fig. 103) and lettered description of the carburetter needs no further explanation. Among other desirable features, a detachable gauze strainer is fitted to filter the petrol before entering the float chamber.

The advantage of the special throttle as illustrated in Fig. 104 over the common type of butterfly valve will be obvious. By means of this old and well-tried sleeve type of throttle, the mixture and the speed can be regulated to a nicety.

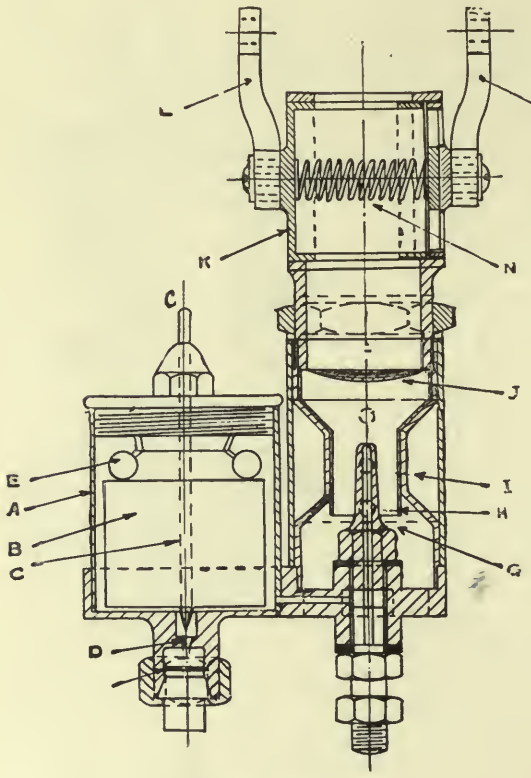


Fig. 103.—Carburetter.

A, Float chamber.
B, Float.
C, Float valve spindle.
D, Seat for float valve spindle.
E, Governor balls for float.
F, Strainer for filtering petrol before entering float chamber.
G, Spraying nozzle.
H, Chimney for spraying nozzle.
I, Hot air jacket.
J, Gauze to prevent back firing in the carburetter.
K, Throttle.
L, Throttle lever.
M, Air lever.
N, Adjusting spring for air lever.

The combination tank shown in Fig. 105 is very compact; everything conceivable is included therein—petrol lubricating oil, pump, two accumulators, and induction coil. The frame tank carrying the necessary fuel is therefore self-contained; everything is fitted in as small a compass as possible and well protected, instead of one member being strapped here and another there wherever an available space on the machine can be found.

No packing whatever is required for the accumulators or induction coil; the accumulators are fitted side by side under a ridge on the inside of the tank, and are also held by the spring clips shown, which, when the door is closed, hold them perfectly secure in position. The induction coil is fixed by means of clips to the door, and the terminals are get-at-able without removing the coil. The lubricating oil tank is self-contained and detachable.

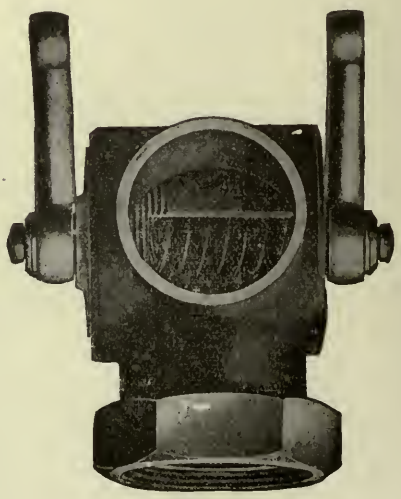


Fig. 104.—Throttle.

Transmission is by means of a 3-ply V belt, copper sewn, with special pulley and belt rim, which, after extensive trials, experimenting with practically every known system, have been found to be the most satisfactory form of transmission for durability, simplicity, elasticity, and smoothness of running. In order to obtain the best results with a belt drive, some little care and attention must be bestowed upon same, as no rider can expect perfection if he rides his machine week in and week out, wet or fine, and never troubles to dress the belt; to do this the belt should first be well soaked and cleaned in warm water, hung up to dry, the dressing well rubbed in from top and

PLATE III.—PETROL AUTOCAR.

bottom, and the sides of the belt scraped with a blunt knife. The accompanying illustration (Fig. 106) will make clear the patent belt fastener. To shorten the belt (this is only necessary when the belt will not drive the machine, which can easily be found out by the engine racing when running uphill), punch out one of the copper rivets by means of a special punch which is supplied, and fix fastener in the manner shown in illustration. Always make a rule of leaving one copper rivet between the fresh hole made and the end of the belt.

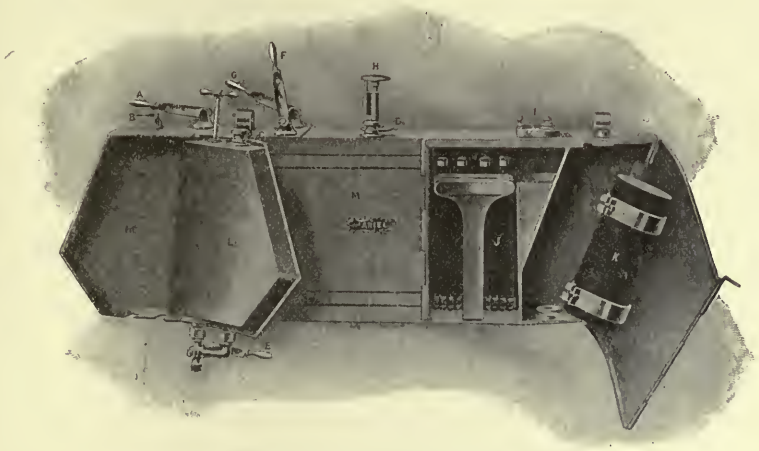


FIG. 105.—Combination Tank.

A, Sparking advance lever.
B, Float wire (petrol).
C, Lubricating oil filling plug.
D, Petrol filling plug.
E, 2-Way cock (oil).
F, Throttle lever.
G, Air lever.
H, Needle valve (petrol)
I, 2-Way switch.
J, Accumulators.
K, Induction coil.
L, Lubricating oil tank.
M, Petrol tank.

FIG. 106.—Belt and Belt Fastener.

THE RYKNIELD CLUTCH

In this car the object of interest in connection with the prime mover is the clutch, which is shown in Fig. 107.

The chief advantage claimed for the Ryknield clutch over all others is that owing to its construction it entirely does away with all "thrust," whether the clutch is in or out, and it also ensures a remarkable soft drive, avoiding all shock both to engine and to road wheels. On referring to diagram it will be found that the clutch is independent of the main fly-wheel of engine, but has a light clutch drum having two sheaves, engaging one on either side, drawn together by springs common to both on the circumference, thus eliminating all thrust on engine or gear box when in or out of clutch. These sheaves at the same time so balance each other when put in gear

as to be silent and perfect in action. From the diagram shown the mechanism is readily followed.

The clutch drum A is keyed to a floating shaft C, one end of which is let into a

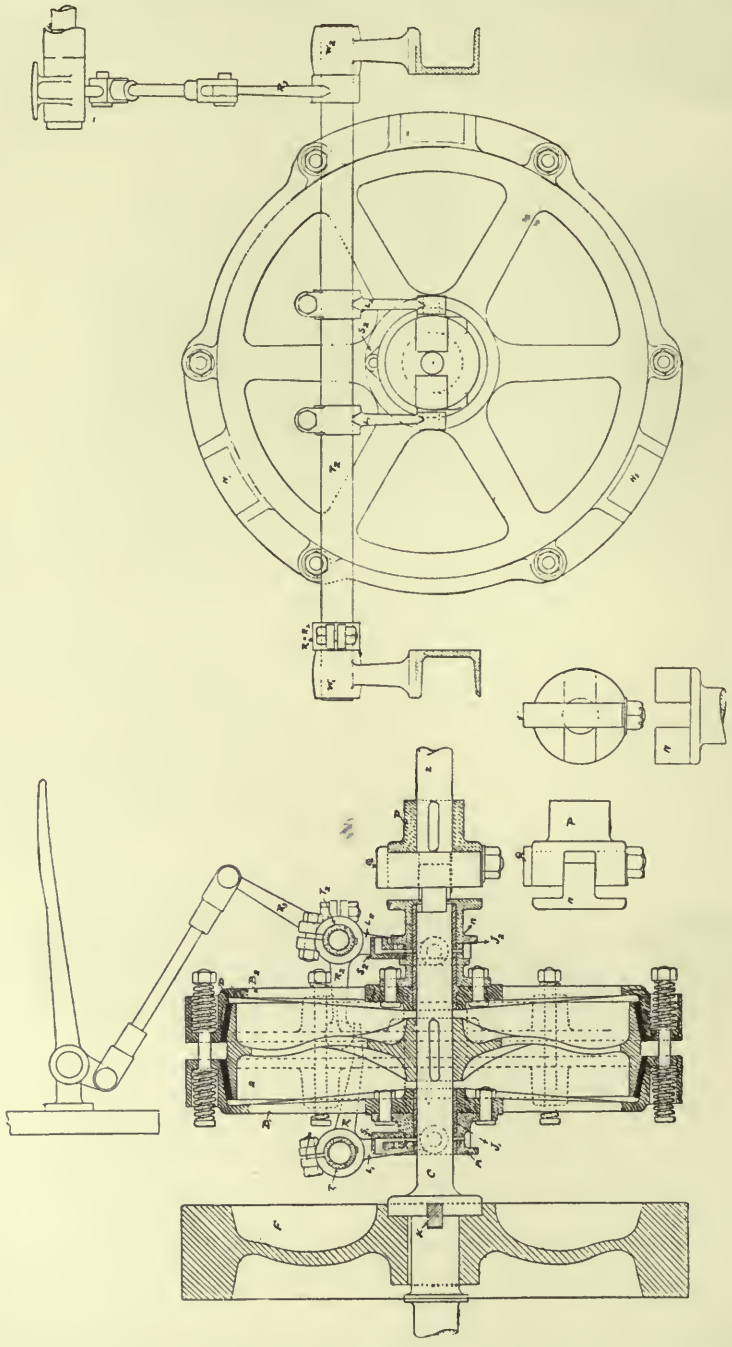


Fig. 107.—Rykneld Clutch.

recess bored into engine fly-wheel F, and deriving its motion by means of a transverse key K.

The other end is butted against a cotter Q, which acts also as a distance piece between it and Z, the change-speed box shaft. It is prevented from falling out of

place by sliding joint N and P. The part P is keyed to Z, having two channels cut at right angles, the horizontal one to take the tongue of shank N, the vertical one being for cotter Q, this preventing N from sliding out, and so securing the clutch and at the same time leaving it flexible.

The two sheaves B_1, B_2 are drawn together on clutch cone by means of twelve springs Y, which are kept in position by pockets and adjusted by means of bolts X.

To unclutch these two sheaves, B_1, B_2 are drawn apart by pressing down foot pedal which actuates cross shafts T_1, T_2, by means of levers R_1, R_2, R_3, causing other levers L_1, L_2 to move outwards, thus drawing B_1, B_2 away from A by means of stirrups S_1, S_2 working in grooves M and N.

B_1, B_2 are prevented from twisting relatively to each other by means of lugs H_1, H_2, H_3 on B, sliding in slots B_2.

To remove clutch, unscrew nut and withdraw cotter Q, allowing the shaft C to slide back and disengage with K and fly-wheel F, then turn the clutch round until the tongue N is in a vertical position so as to allow it to drop bodily downward out of the stirrups.

Lubricating is done by means of oil pipes from dashboard attached to top of stirrups so as to let the oil down between the faces of the shanks and stirrups through small holes in N and M to the bearing.

THE WOLSELEY SIX HORSE-POWER AUTOCAR ENGINE

This engine is built for the little autocar made for two, the chassis of which is shown in Figs. 108 and 109, and is an example of the return to simplicity in design and

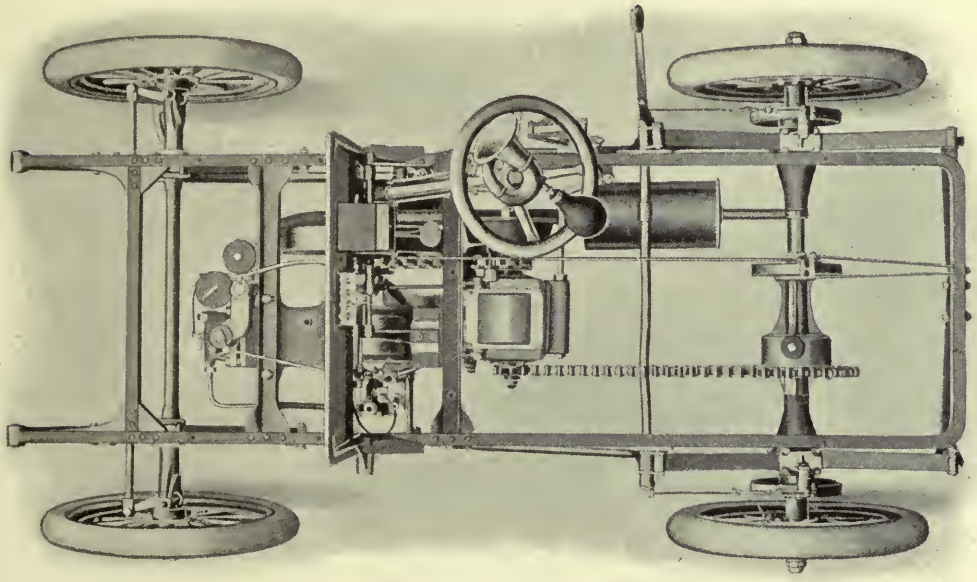


FIG. 108.—Wolseley Chassis.

reliance upon good design and high-class workmanship rather than a multiplication of useless parts. The design is altogether rational, and can be appreciated by the engineer. We are only concerned here with the engine and gearing, which are shown in Figs. 110 and 111.

The cylinder, which is suspended from the two transverse members of the frame, has

a bore of 4½ inch with a 5-inches, stroke; and running at a normal speed of 800 revolutions per minute, it develops 6½ brake horse-power. As shown in the detail (Fig. 110), it consists of a cast-iron liner placed inside an aluminium alloy barrel, the space between serving as a water jacket. The aluminium casing is extended to form a complete chamber for the crank and for working parts, and the bearings are carried in the ends of this casing, as shown in Fig. 110. The lower part of the chamber may be removed without disturbing the shaft, and there is at the bottom a drain cock to draw off waste lubricant. The cam shaft and the spur wheels driving it are, as shown in Fig. 110, carried within the lower part of the chamber. This shaft is fitted with a sliding sleeve, which brings half-compression cams into play to facilitate the starting of the engine. The motion of these cams is transmitted to the exhaust valve by a rocking lever, the pivot of which is fitted with half bushes, so that no oil can flow from the crank chamber. The end of this lever is held up to its work by a laminated spring. The valve gear, which is accessible from the bonnet of the car, is of very simple construction. The inlet valve is placed immediately above the exhaust valve,

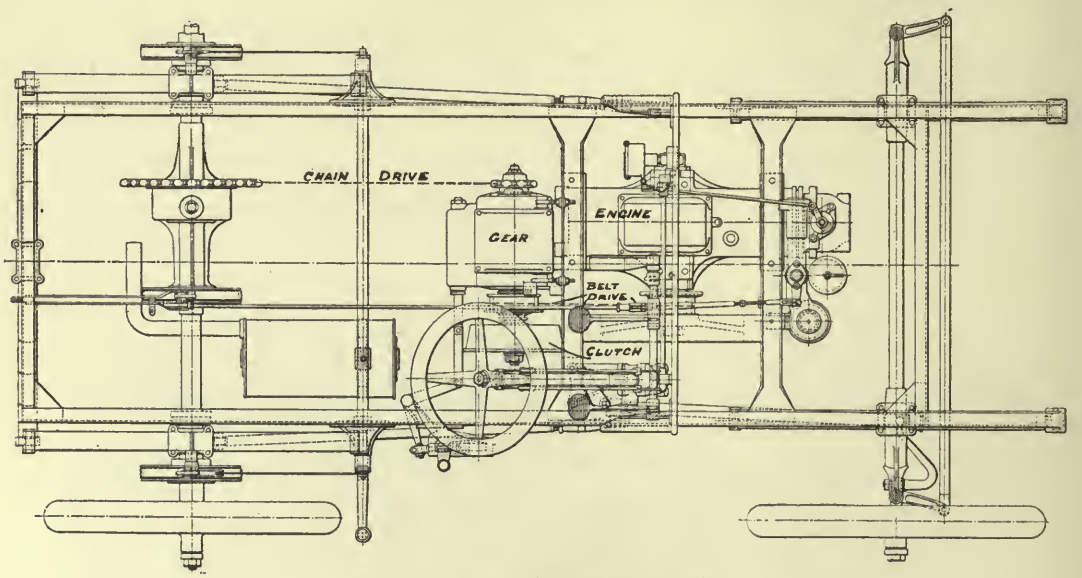
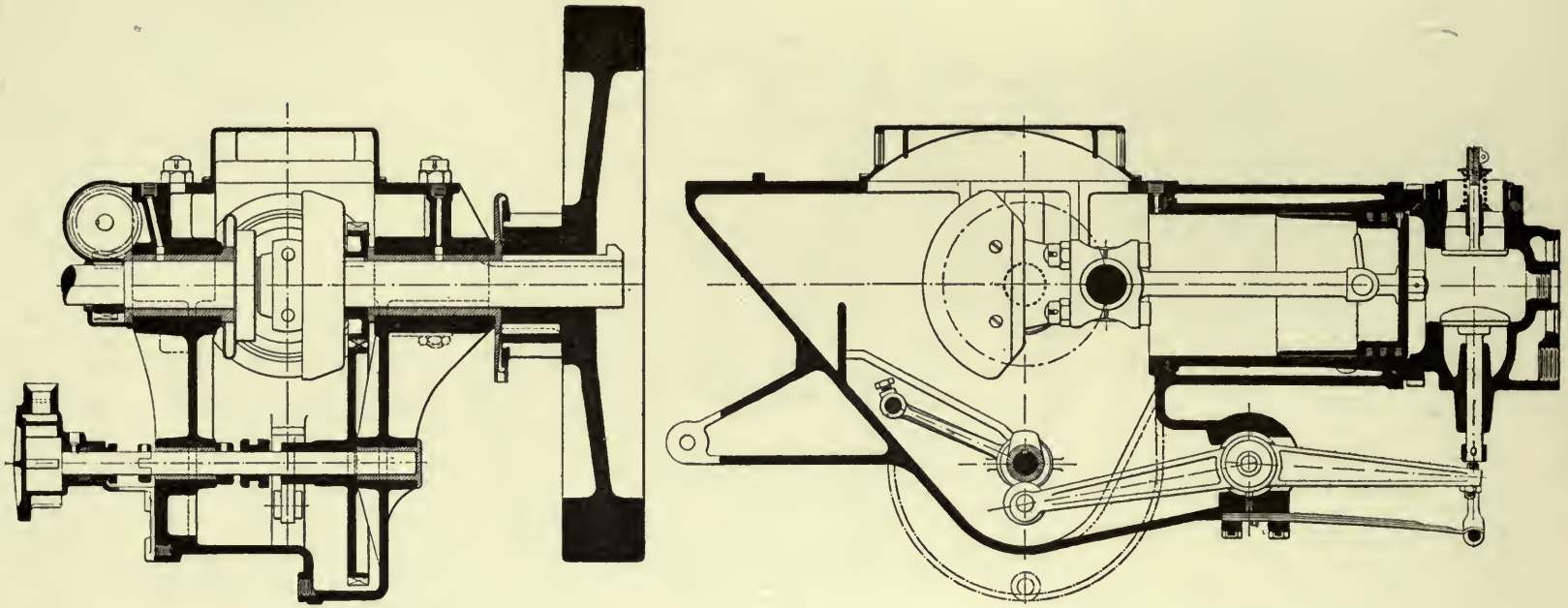


FIG. 109.—Plan of Wolseley Chassis.

and both work vertically. The valves are fitted with a special silencing arrangement, which prevents tapping action on the seats; this further lessens the wear. As is shown by the sections, the whole valve gear can be lifted bodily from the cylinder, being secured to it by flanges and studs. The commutator is actuated by a worm wheel fixed on the end of the crank shaft; ignition is high tension, worked by coil and accumulator, and the carburetter is of the float-feed type, with gravity feed from the petrol tank. The regulation of supply to the motor can be controlled by a hand-operated throttle. It should be noted that the connecting rod is a stamped forging, connected at the small end to a hardened steel forked end, forged in one piece with the shank passing through the piston, and secured by an outside nut, slightly riveted to prevent any tendency to loosen. The piston is cast of a uniform thickness, in order to avoid any tendency to unequal expansion or distortion.

The crank shaft is a solid forging. The system of lubricating the pins is as follows. Outside the crank cheek and near to the bearings there is a groove formed in the middle, and from it a hole is drilled to the centre of the crank pin. The oil which is splashed into the groove is thrown by centrifugal force into the large end of the



Sectional End View.

Sectional Elevation.

FIG. 110.—Wolseley Single-Cylinder Engine.

connecting rod. The method of securing the fly-wheel is shown in Fig. 110. It will be noticed that the wheel has a long boss, and on this the chain pinion is mounted.

The transmission gear, which is shown in detail in Fig. 111, has the important advantage that all the shafts concerned are parallel to each other and to the crank shaft. This obviates the loss of power involved in the case where the driving force has to be transmitted at a right angle by bevel gearing. Three speeds are provided for forward running, in addition to the reverse, these forward speeds being 7, 13, and 20 miles per hour respectively when the motor is running at its normal speed of 800 revolutions; but it is possible to attain an accelerated speed of 25 miles per hour. The upper shaft, in Fig. 111, carries the fixed gear wheels, and runs in ball bearings, being operated, of course, by a Renold's chain from the crank shaft. For this purpose there is an extension of the shaft through the gear box, carrying a cone clutch, which itself is entirely enclosed. On the outer portion of this clutch, between it and the gear box, is a Renold chain wheel, which transmits the

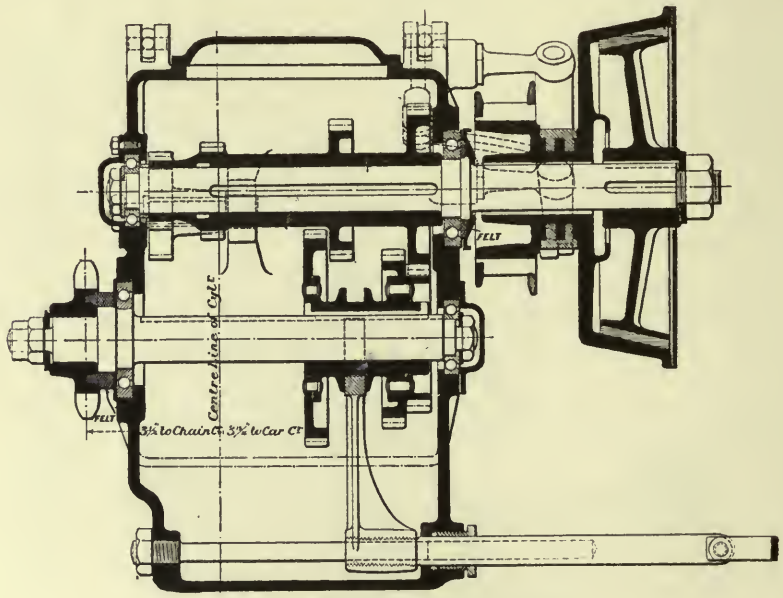


Fig. 111.—Wolseley Transmission Gear.

power from the motor to the gears. The clutch is actuated by a right-foot pedal, which, along with a second, a left-foot pedal, is placed conveniently for the driver, the second one controlling a band brake. The lower shaft carries the sliding gear, which is controlled by a hand lever placed to the right of the driver, and operating through the sliding bracket shown in the section. The speed changes and reverse action are all controlled by the one lever. This sliding-gear shaft also runs in ball bearings, and projects beyond the gear box in order to carry a sprocket-wheel, over which there runs a roller chain, transmitting motion direct to the rear axle. The complete train of gear is encased in an aluminium alloy casing, the lower part of which can easily be removed for examination.

TWO-CYLINDER ENGINE

Fig. 112 shows a section of a 2-cylinder horizontal petrol engine of simple and effective design, fitted with an oil pump and particular attention to lubrication. The design of the cylinder is also worthy of note, being cast all in a piece with a small end

cover which carries the ignition plug. While forming all one casting head and cylinder, the valves and ignition plug are yet quite accessible, and the machining of the valve seats and boring of the cylinder are quite simple matters.

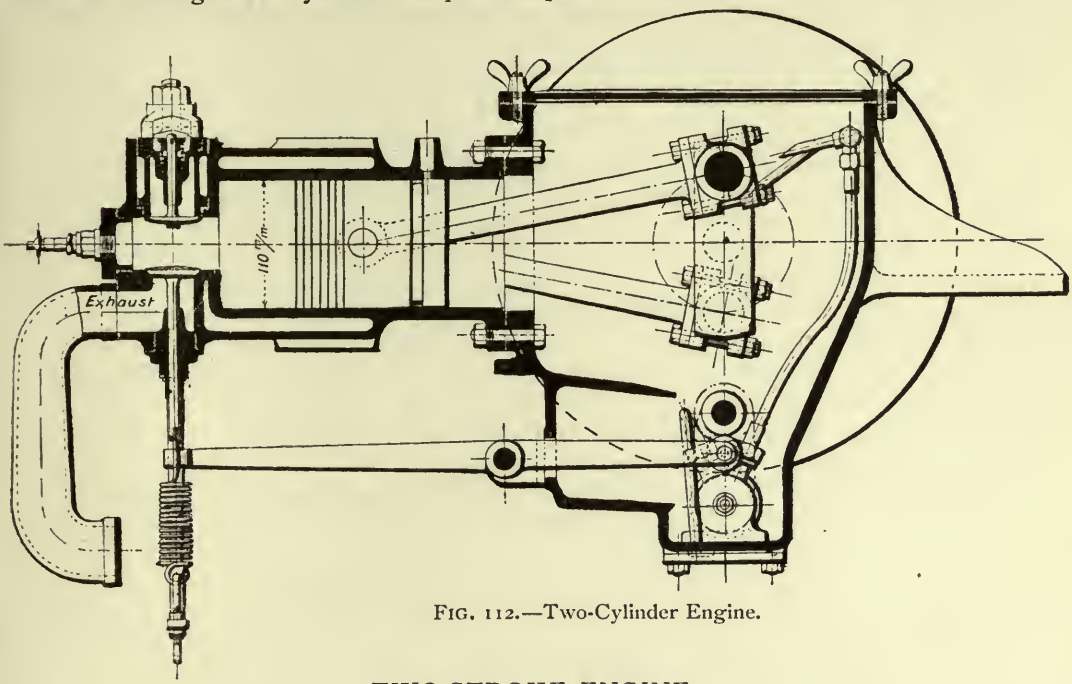


FIG. 112.—Two-Cylinder Engine.

TWO-STROKE ENGINE

The construction of the 2-cylinder engine known as the Hardt engine is shown in Fig. 113, the special feature being that a scavenging charge of air is admitted to the cylinder before the fresh charge of combustible mixture is forced in. The cylinder Q has its upper portion water-jacketed, and it is constructed with four ports in addition to the ordinary exhaust ports, which are not shown in the sections, but are uncovered by the piston just before it reaches the end of its down-stroke, as in most engines of this kind. The explosive charge is drawn into the crank chamber R when the piston has nearly completed its upward stroke, after it has created a partial vacuum in the crank chamber. At the same time that communication is established between the carburetter R_1 and the crank chamber R, a pocket T_2 in the piston connects the ports Q_1 and Q_2 in the cylinder together, allowing air to flow into the pipe-fitting S, which connects the port Q_1 with the lower port Q_2; the result is, that at the same time that the fresh charge is entering the crank chamber the pipe-fitting S is being filled with fresh air. As the piston T descends it first covers the ports Q_1 and Q_2, and then compresses the charge

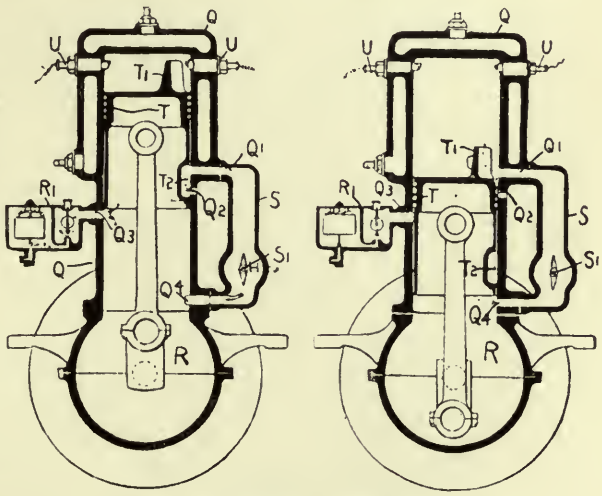


FIG. 113.—Hardt 2-Stroke Engine.

in the crank chamber R and the air in the pipe-fitting S. When nearing the bottom of its stroke it uncovers the exhaust ports, and a moment later it uncovers the port Q_1, opening communication between the crank chamber and the upper part of the cylinder. The air in the pipe-fitting S is first forced into the cylinder, sweeping out the products of combustion before the combustible mixture finds its way into the cylinder, the baffle plate T_1 being fitted above the piston to assist the scavenging action as usual. Anything following the burnt gases out through the exhaust ports will be pure air instead of combustible mixture, and consequently the engine is rendered more economical than are most 2-cycle machines. During the upward stroke of the piston the combustible mixture is compressed as in other engines, and is ignited by the high-tension spark plugs U. Another advantage which is claimed for the engine is that there is very little chance of the fresh charge becoming ignited by the remaining hot gases in the cylinder.

The power of the Hardt engine is regulated by a throttle valve S_1 in the pipe-fitting S, this valve regulating the volume of the charge forced into the working cylinder. The 2-cylinder engine has a bore of 105 millimetres and a stroke of 120 millimetres, and develops about 15 brake horse-power at 1500 revolutions per minute. It is not fitted with an automatic governor, but its normal speed is 900 revolutions per minute, and it is capable of doing useful work at any speed between 250 and 1500 revolutions per minute. The exhaust gases escape through a series of holes passing through the walls of the cylinder into a port formed in the casting, and are led by the pipe-fitting in the central exhaust pipe.

GOBRON-BRILLIÉ ENGINE

One of the rare examples of a positive feed alcohol carburetter being fitted to an automobile motor is shown in the accompanying illustration (Fig. 114) of the Gobron-Brillié engine. This is remarkable from the fact that, contrary to all other carburetters and vaporisers for this spirit, there is no provision for raising the temperature of the alcohol, and therefore its success would seem to have a close relation to the construction of the engine itself. The carburetter has a disc carrying a number of small pockets, each carrying exactly the quantity of alcohol required for a cylinder charge. It revolves in an alcohol chamber communicating with the constant level chamber. The disc is actuated by a pawl and ratchet, which take their drive from an eccentric on the crank shaft. The eccentric is connected with the pawl by a regulator in the form of a variable bell lever which can be adjusted to vary the speed of the engine. With each turn of the crank shaft the pawl and ratchet turn the disc to bring one of the pockets opposite the spray nozzle, which projects into the air tube leading to the induction valve. There is thus an ordinary spraying close to the induction valve, without any vaporisation or special arrangement for facilitating the mixture, which is one of the principal features in all the other alcohol carburetters. It is evident, therefore, that if alcohol can be burnt economically under these conditions, it must be attributable largely to the design of the engine. If we look at the characteristics of alcohol, as explained by those who have carried out experiments with the spirit, we find that the 10 per cent. of water contained in alcohol is flashed into steam, with the result that an expansive force is given to the charge. The engine must consequently be designed to provide for this expansion, and it is remarkable that the only two motors in France that run better with alcohol than with petrol are the Gobron-Brillié and the Bardon, in both of which the charge is fired between two pistons. In the Gobron-Brillié vertical 2-cylinder engine the upper pistons are joined by a yoke, at the ends of which are connecting rods to the crank shaft, the outer cranks being set at an angle of 180° to the inside pair. The bore of the cylinder is 110 millimetres, and the combined stroke of the two pistons is 200 millimetres, so it will be seen that the expansion of the alcohol gas can be used to its fullest advantage. The stroke of each piston is not the same, the upper one having 88 millimetres and the lower 112 millimetres, this being done to provide for the unequal

weight of the moving parts. Considering that the alcohol is introduced into the

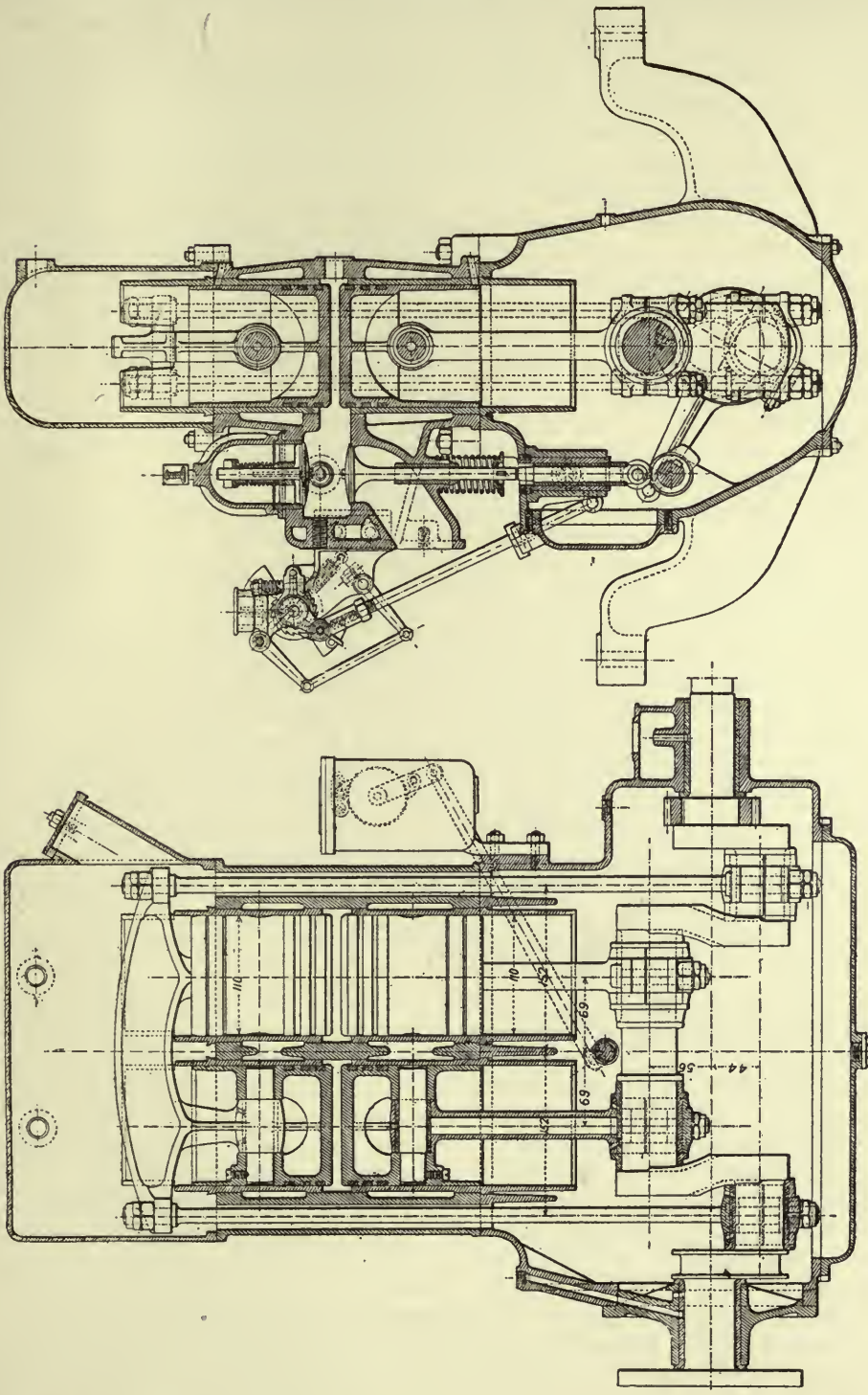


Fig. 114.—Gobron-Brillié 2-Cylinder Alcohol Engine.

cylinder in exactly the same way as petrol—that is to say, without heating and vaporising, the results obtained in tests with the Gobron-Brillié engine are remarkable.

In a motor with a bore of 92 millimetres and a combined stroke of 170 millimetres the power developed steadily rose from 9 horse-power at 650 revolutions to 13 horse-power at 1000 revolutions, and remained constant to 1100, when it fell to $12\frac{1}{4}$ horse-power at 1250 revolutions. With petrol the engine developed $8\frac{1}{2}$ horse-power at 675 revolutions, and rose to a little less than 13 horse-power at 1150, when it fell suddenly to $11\frac{1}{2}$ horse-power at 1250. Still better results were obtained with carburetted alcohol in an engine with a bore of 80 millimetres and a combined stroke of 140 millimetres. At 600 revolutions it developed $5\frac{1}{2}$ horse-power, and at from 1000 to 1150 there is a flat curve through the line representing 8 horse-power, with a fall to $7\frac{3}{4}$ horse-power at 1200 revolutions. When using petrol the same engine developed 5 horse-power at 750 revolutions, and rose to $7\frac{3}{4}$ horse-power at 1150, falling to $7\frac{1}{4}$ horse-power at 1200 revolutions. It is clear, therefore, that while alcohol has a lower calorific efficiency than petrol, the calories can be used to much better advantage in a suitably designed motor, and much less heat is carried away by radiation, as the alcohol engine runs much cooler. This fully bears out the contention that the success of alcohol depends quite as much upon the engine as upon the carburetter.

This concludes the description of modern petrol prime movers and their gearing as employed in road vehicles. There are many other cars, but it is sufficient for the purpose of this work to have a knowledge of a few; they differ but little, and that only in detail.

If one may express an opinion applying generally to motors or autocars, I would say that strength of parts and area of wearing surfaces should be much greater than they generally are. The craze for racing has brought about the desire for small weight and size, resulting in autocars of a very short and highly expensive working life. And further, the complication of parts does not always make for improvements. It seems that the technical education of engineers responsible for designing of all kinds of machinery nowadays makes them fearless in piling on delicate and intricate mechanism to effect some not very important improvement, forgetting that real improvement consist in reducing the parts and effecting some desirable result by some simple means. All prime movers went through the stages; first a simple machine, these improvers take it up and pile up every conceivable addition to the primitive machine, in the belief that every addition to the already complicated mechanism must be an improvement. The petrol motor is in this second stage yet, and is about to enter the third stage, in which it will be studied scientifically, the why and wherefore for its construction and design being judicially, coolly, and rigorously investigated apart from any question as to commercial matters altogether.

The fuel question concerns the autocar section of internal combustion engines much more than any other class; it also concerns the sporting and pleasure boat section. Petrol has many advantages, but Dr. Ormanby has shown that alcohol has more advantages. The author believes that there is a wide and profitable field for investigation into the properties of mixed fuels. Taking alcohol as a solvent, mixtures of alcohol and petrol, alcohol and oils, some rough tests gave remarkable results, but as no scientific tests were made it would be useless to generalise upon the results. It is interesting to note that mixtures and solutions of explosives have given remarkable results in gunnery, and it may be that some compound fuel may far exceed in value any of the elementary fuels hitherto used. The autocar fraternity should press the Government incessantly in order to obtain alcohol for power purposes free of duty; it can easily be made undrinkable, so that the present revenue would not be injured. With alcohol as a basis there is no doubt a fuel safer, pleasanter, and probably cheaper than petrol can be produced.

In Volume II. of this work the author took exception to the extended use of petrol on boats, and expressed fear of accidents, which on an autocar would be negligible but on a boat might be very serious. An object lesson on the point has already occurred in some petrol boat races at Monaco. It is thus reported in the *Automotor Journal* of 16th April 1904:—

"For the Friday, racers of 12 to 18 metres and cruisers from 8 to 12 metres ran off

their events, and an unrehearsed incident, the sensation of the week, was reserved for this day. *Parisienne II.*, the 70-foot boat fitted with three Mors motors, soon after making a poor start, was seen suddenly to burst into flames, the unwonted occurrence being heralded by a cannon shot from the Antoine fort." The occupants of the boat "soon found their positions a bit too hot to retain, and they all four took to the water for safety, whence they were speedily rescued by another competitor, the burning boat being promptly taken in hand by the torpedo destroyer *l'Epieu*, which was in attendance upon the racers. No serious harm came to the 'crew,' but the boat was completely burnt out, the steel hull, after a considerable time, only remaining to tell the tale. The fire was finally extinguished in the bay by a good application of sand. A defective pipe was stated to be the cause of the disaster. Subsequently she was re-hoisted into the Exhibition building, where, needless to say, she was a source of the keenest interest."

This is just exactly what was to be expected. I pointed out that if a fire occurred on a car the occupants could jump off, but in a boat they would have to choose between fire and water. In this case, fortunately, help was at hand to rescue the boatmen from the water, having saved themselves from fire by going overboard. There are other dangers attendant upon petrol motors for boating purposes, so that it is all the more important that the fuel question should be given some paramount position in autocar circles. I refer to this point again because some critics rather objected to my previous hints in Volume II. regarding possible accidents.

Petrol engines or oil engines of small size are also used for direct driving dynamos and for portable pumps and other minor purposes with considerable success.

Endeavours to get reliable information regarding autocars designed to consume ordinary paraffin oil have failed to bring forth anything worth recording. There are advertisements of such engines, but without details and particulars they are of no interest whatever.

It is to be feared that the paraffin oil motor is not a success on autocars; the vaporiser is no doubt the difficulty. Requiring a lamp flame to heat it before starting, it also requires a larger engine for the same power. Both these requirements are of no account in stationary engines, but they weigh against an autocar engine—more is the pity, for paraffin is safer by far than petrol.

An empirical rule for calculating the horse-power of petrol and paraffin in the same engine has been proposed, and is given here for what it may be worth. It certainly gives one a very fair idea of the horse-power of an engine from the cylinder dimensions, taking a piston speed of 240 metres per minute for all engines.

For petrol, take the contents of the cylinder working space in cubic centimetres and divide by 150.

For paraffin the same, but divide by 250. Thus—

For petrol, $\frac{\text{Area of piston} \times \text{stroke}}{150}$; for paraffin, $\frac{\text{Area of piston} \times \text{stroke}}{250}$ = horse-power.

Suppose stroke 10 centimetres and area 80 square centimetres, then for petrol we get $\frac{10 \times 80}{150} = 5.3$ horse-power; and for paraffin $\frac{10 \times 80}{250} = 3.2$ horse-power. This is only approximate, but near enough for estimating the power of an engine when inspecting or discussing a motor car and its fittings.

In English measure a rough rule is to take the area of the piston, say 12 inches, and multiply this by the stroke, say 4 inches, and divide by 10 for petrol and 15 for paraffin fuel, in a 4-stroke engine. Thus—

$\frac{4 \times 12}{10} = 4.8$ horse-power for petrol, and $\frac{4 \times 12}{15} = 3.2$ for paraffin fuel.

It must be always remembered that these powers are to be got only at speeds of piston of about 800 feet per second; if the piston speed is more or less, the power will be directly proportionally more or less. And also that the formulæ is empirical, and not to be taken instead of actual brake tests where accuracy is necessary.

THE OECHELHAEUSER GAS ENGINE

This engine has just recently come into prominence as one for large powers using blast furnace or producer gases. It is worthy of attention, and as the details of its working have been published a reference to it here is given in order to make our description of modern engines complete.

It operates somewhat different from other engines, in having two pistons and two sets of ports covered and uncovered by the pistons. One set admits the fuel and air under pressure from a pump, and the other set simultaneously allows the exhaust to be swept out by the incoming fresh charge. It is claimed that this method of working does away with all valves on the engine; that, however, cannot properly be allowed, for although there are no valves on the cylinders, the charge of fuel and air must all pass through valves on the pump, and as the pump is an essential part of the engine, the engine has valves, and these valves are subject to any trouble from dust or tar in the gases quite as much as they would be if on the cylinder. The old Trent gas engine worked on the same principle.

In this country the engine is made by a large firm of engineers, and on the Continent by M. A. Borsig of Tegel, Berlin. Single-cylinder engines of this type have been made up to 1500 horse-power.

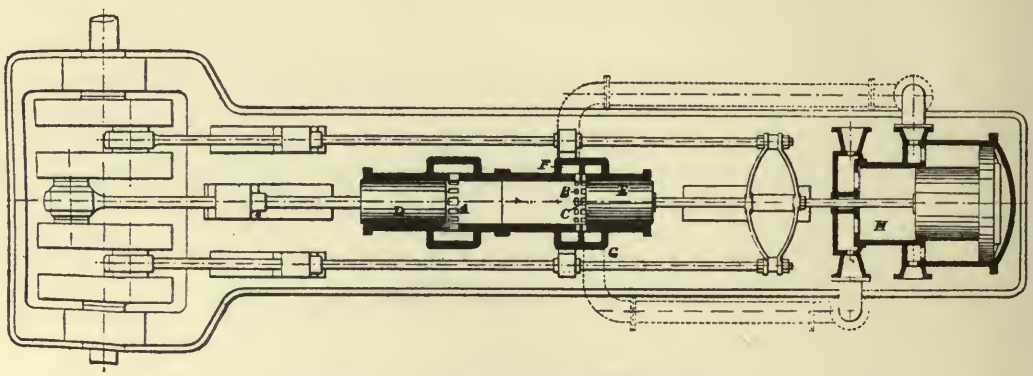


FIG. 115.—Oechelhaeuser Gas Engine.

The main feature of the engine is shown in the diagrammatic plan partly in section (Fig. 115). The cylinder is open at both ends, and has two pistons; the cylinder, in fact, may be considered as two cylinders end to end, each with its piston. One piston is connected in the usual way to a crank shaft by a connecting rod, the other by a cross-head and two side rods connects to two cranks opposite to the centre crank. The pistons were therefore in opposite directions, so that the reciprocating parts are balanced.

As the pistons move towards the outer ends of their strokes, the ports A, B, and C are uncovered one after the other. When the piston D opens the ports A, the products of combustion pass out through the exhaust ports. Immediately afterwards the piston E opens the ports B, and atmospheric air passing in clears out the cylinder. The ports C now open for the admission of gas, and this, combining with the air, forms the explosive mixture. The pistons are now on their inward stroke, the mixture is compressed and exploded, driving the pistons outward, and completing the cycle. It will thus be seen that a complete cycle is passed through in each revolution of the crank shaft. The chambers F and G, through which air and gas pass, are kept at a pressure of $4\frac{1}{2}$ lbs. to $5\frac{1}{2}$ lbs. per square inch by the pump H, which is driven by the back piston rod, and which can be placed either on the main bed-plate or beneath the engine, and driven by suitable levers. It is thus ensured that air and gas enter the cylinder at the above-named pressure. In order to prevent unburnt gas passing through the exhaust

during the admission and exhaust periods, the dimensions of the cylinder are so arranged that, when giving off the maximum of power, not more than 70 per cent. of its volume is filled with the explosive mixture.

Owing to the absence of admission valves, it is possible to make the passages for air and gas sufficiently large, so that the above-mentioned pressure of $4\frac{1}{2}$ lbs. to $5\frac{1}{2}$ lbs. is quite sufficient. The power consumed by the pump cylinder is small. The simple air and gas valves which are required for governing are placed between the cylinder and the pump.

The combustion chamber is without projecting parts or corners where residue can accumulate. This, combined with the position of the ports at each end of the cylinder, ensures a thorough cleaning of the cylinders in the "scavenger" air. Early explosions are therefore avoided, and no extra precautions have to be employed in this respect.

For starting the engine compressed air is employed. For governing the before-mentioned bypass valves ensure that an explosive mixture in the right proportion is formed in the cylinder, even under the lightest loads. As in this case only small quantities of gas are necessary, an arrangement is provided by which this explosive mixture is always compelled to pass directly over the igniters, this arrangement being controlled by the governor. The latter is driven by gearing, and is so constructed that the speed can be adjusted by ± 5 per cent. when running. The governor itself is sufficiently sensitive to allow of a variation speed of only $1\frac{1}{2}$ per cent. to 2 per cent., with a variation in load of 25 per cent. Between full and no load the variation does not exceed ± 5 per cent. to 6 per cent.

Two electric igniters are provided, and so arranged that the point of explosion can be varied as desired. The air and gas pumps are, as will be seen from the drawing, separate, being operated by a differential piston.

M. H. ROBINSON'S INTERNAL COMBUSTION ENGINE

This engine, described in Patent No. 8495 of 1903, is of interest to marine engineers as a recent development which has considerable promise. An engine according to this invention is constructed with two cylinders C, D, with their axles parallel, and preferably as close together as possible. The compression spaces of the two cylinders are connected by a passage E and form one compression space, the whole arrangement forming a U-shaped combination. The two pistons work in these cylinders

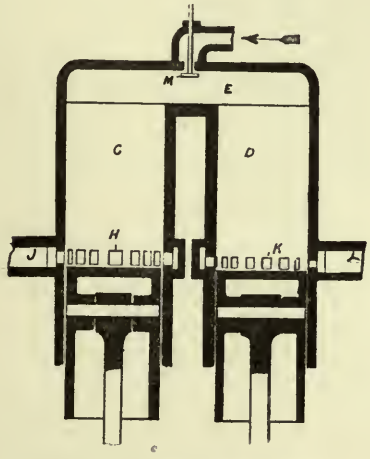


FIG. 116.—Robinson Engine. Single Acting.

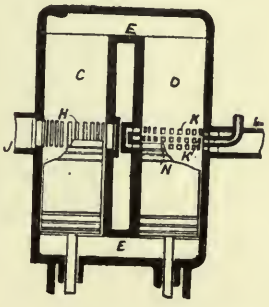


FIG. 117.—Robinson Engine. Double Acting.

synchronously, being connected by piston rods to a common cross-head with one connecting rod, or to two separate connecting rods working side by side on to one

long crank pin or on to separate cranks. Each piston at the end of its forward stroke uncovers a ring of ports in the wall of its cylinder. The ring of ports H in the cylinder

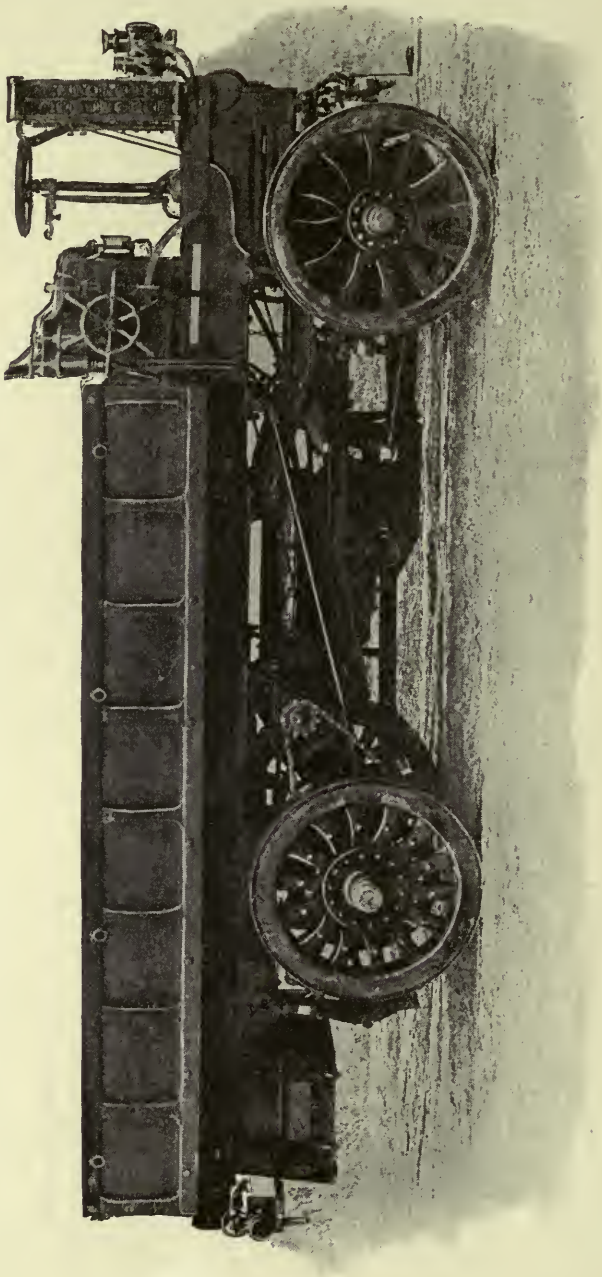


Fig. 118.—Cadogan Petrol Lorry.

C is connected to the exhaust pipe J, and the ring of ports K in the cylinder D admits, when uncovered, a supply of air under pressure supplied through the pipe L by a pump attached to the engine. The charge of gas is admitted through a valve M. The

engine may work on the 2-stroke or 4-stroke cycle, and may be either single-acting or double-acting. In the latter event the two cylinders are connected at both ends in the manner explained, and have piston rods passing out through stuffing boxes. Fig. 116 shows a single-acting 2-cycle engine, and Fig. 117 a 4-cycle engine, the gas in this case being introduced through a ring of ports N.

The only feature to which exception might be taken in this type of engine is the necessity for a pump of some sort to force in the gas and air under some pressure. But the improvements overcome one of the difficulties of 2-stroke engines in preventing the mixing of the exhaust gases with the fresh charges.

By some recent improvements this double-piston engine with two pistons in one cylinder, of which type Oechelhaeuser was the originator, and introduced the cylinder ports to be covered and uncovered by the piston instead of an inlet valve. D. Clerk had previously used covered and uncovered ports by the piston, instead of an outlet or exhaust valve. The difference between Clerk and Oechelhaeuser is considerable, but the difference between Oechelhaeuser and Robinson is not much. Oechelhaeuser puts two cylinders end to end, each with a separate piston. Robinson puts two cylinders, each with a piston side by side. In both cases the cylinders are in open communication with each other, and both of them require pumps and pump valves, so that they are, strictly speaking, not valveless engines.

THE CADOGAN PETROL LORRY

We have already described the Gobron-Brillié petrol engine. It has been applied to heavy traction work in a 34 horse-power lorry shown in Fig. 118 capable of carrying five or six tons. The transmission gear is by chain and wheels, giving four speeds and reverse. It carries 20 gallons of petrol, sufficient for a 100 miles journey with a 5-ton load, consuming 0.2 gallons per mile at $7\frac{1}{2}$d. per gallon, the density being 0.74.

The fuel space is said to be one-tenth of that required by steam, and the weight of fuel one-sixteenth that of coal.

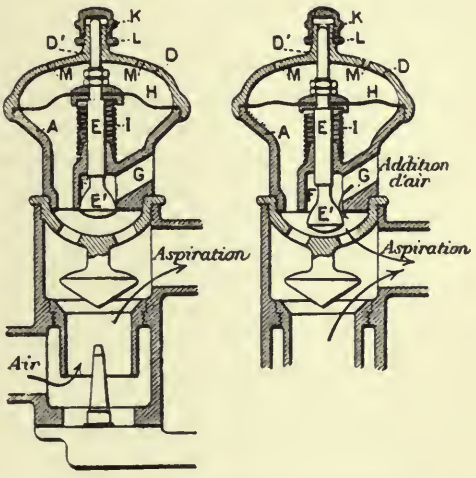


FIG. 119.—Gobron-Brillié Carburetter.

The carburetter of the engine is of the self-regulating type, shown in Fig. 119. The supplementary valve E opens when the demand increases for mixture and additional air enters, as shown in the right-hand sketch. The mixing chamber is heated by the exhaust.

CHAPTER IV

THE ELECTRICAL AUTOCAR

This car has made little progress here, although in America and on the Continent of Europe inventors still persevere. There is no practicable generation of electrical energy, hence the supply of electricity for autocar must be obtained in a roundabout way, by converting the energy of fuel in a prime mover into electricity by means of a dynamo-electric machine. This dynamo-electric machine and prime mover may be carried on the car, as it is done in the case of the railway car shown and described already (page 20), and the electricity used as the transmitter between the prime mover and the car axles. This method is the best electric car system at present.

The other system in use employs accumulators of electrical energy, sometimes called secondary batteries and electric storage batteries. In this system the electrical energy is obtained from any convenient supply, and is stored up for use in the batteries on the car.

The batteries are the difficulty in this system; they are heavy, bulky, and noisy, but that could be overlooked if they were at all durable, and did not require incessant careful attention. As to their weight, it may be said at once that no battery has ever exceeded an output of energy per lb. of its weight of more than 15 watt-hours, and at that high output per lb. the battery is very delicate and of little practical use. The weight must be increased so that at 12 watt-hours per lb. of battery it becomes tolerably durable, but still requiring great care; but when the weight is increased to 10 watt-hours per lb. of battery at normal discharge rates, it reaches its most enduring form.

This jargon about watt-hours may not be clearly understood, so that an example is given to show the meaning of the terms.

Suppose a car fitted with 8 horse-power in motors; to the electrician a horse-power is equal to 746 watts. A watt of power is given by an electric pressure of one volt and a current of electricity of one ampère. The electric pressure employed on cars is usually 80 volts. With these figures we can now make a calculation.

Eight horse-power equals $8 \times 746 = 5968$ watts. As we know the electric pressure is 80 volts, we can find the electric current required from the battery by dividing the watts by the pressure in volts $= \frac{5968}{80} = 74.6$ ampères of current.

Now we must take the element of time into account. We shall suppose that it is desired to get this 8 horse-power on the car for five hours' running, that is, $8 \times 5 = 40$ horse-power-hours, multiplying the time by the power. Similarly we get $5968 \times 5 = 29{,}840$ watt-hours, the electrical energy required to run the car for five hours at 8 horse-power. Now, it will be clear that if the battery is to be used at an output of 10 watt-hours per lb. of its weight, its total weight will be $\frac{29{,}840}{10} = 2984$ lbs. If we could run the battery with safety at 15 watt-hours per lb. the weight would come out $\frac{29{,}840}{15} =$

2000 lbs. nearly. These figures apply to the lead cells, but they also apply to Edison's new alkaline cells, which do not, so far as one can gather at present, give more than 11 to 12 watt-hours per lb. of cell or battery.

The greatest drawback, however, is the continual care required with the batteries. The author has had years of experience as a maker and user of batteries, and tried for long to run a car by their means, but the trouble of the battery proved too much. Although every care and precaution was taken to keep them in order, they failed. The cause is not far to seek,—the load on the motors in a car is variable through a large range, climbing a stiff hill demands a large effort. Starting up rapidly also calls for a large power. The power required may be sometimes three times the normal. Batteries will not stand that sort of load for long. Sudden large rushes of current through the batteries disintegrates the plates; the jolting and vibration assisting in the breaking down process.

In this respect the new Edison cell is far superior to the old lead cell. The plates are much stronger, being nickel and steel, and it stands much rougher work than the lead cell. The lead cell and its construction are well known, and information regarding them easily obtained. The Edison cell may be briefly described here, as it will no doubt be of use on cars. Its plates consist of grids made of steel. Into these grids, pockets are fixed. These pockets are made up of thin perforated steel, nickel plated and filled with active material. Its dimensions complete are about 3 inches long, $\frac{1}{2}$ inch wide, and about $\frac{1}{8}$ inch thick.

The filling material used for the positive plate is hydrated peroxide of nickel (Ni_2O_3 3 H_2O), obtained from a hot solution of nickel nitrate by precipitation with magnesia and further treatment by chlorine, and mixed with flake graphite. The material originally used in the negative plate was a mixture of protoxide and sesquioxide of iron (80 parts) with 20 parts of graphite; this, however, has apparently been superseded by a paste containing iron 64, copper 30, and mercury 6 per cent., the amalgam taking the place of graphite. The pastes are kneaded under rollers with a solution of KHO, compressed into pellets under a pressure of 300 kilogrammes per square centimetre, and fed into the pockets, which at the same time are closed. This work is done by women. The filled pockets are placed in position in the grid, and the whole hydraulically compressed, the pockets being thus firmly attached to the grid, and corrugated widthwise under a pressure of 90 tons per pocket, or about 200 tons for the whole. The complete electrode weighs about 138 grammes. The total weight of active material appears to be about 2000 grammes. The plates are separated by means of star-shaped ebonite rods, the space from plate to plate being slightly above 1 millimetre. The whole is insulated from the container by means of ebonite sheet and strips.

The weight of a 28 plate cell is about 17.8 to 18 lbs.

The electrolyte is a 20 per cent. solution of pure caustic potash in distilled water, its specific gravity being 1.176 at 15° C. At the end of charge it is found, according to Edison, that the positive pockets are filled with NiO_2, and the negatives with reduced iron.

Some tests by M. Hospitalier are here given:—

TABLE II.—EDISON CELL.

Watts.	Watts: Kilogrammes.	Watts-H.	Watts-H.: Kilogrammes.	Rate of Discharge. Ampères.
36.7	4.61	215	26.9	30
70	9	199	24.9	60
100	12.8	186	23.2	90
126.2	16.2	183	22.9	120

TABLE III.—LEAD CELLS.

Contal.		Fulmen.		Blot-Fulmen.	
Watts per Kilogramme.	W.H. per Kilogramme.	Watts per Kilogramme.	W.H. per Kilogramme.	Watts per Kilogramme.	W.H. per Kilogramme.
2	33·4	2.75	27·5	1.9	19
2.8	32·7	5	24·7	3·4	17·1
5	29·5	6.8	20.3	5	15·2
7·4	22.3				

The efficiency is also very low, only about 60 per cent. at the best, and 50 per cent. under normal conditions; but we could suffer even that, and the bulk and weight, if the cells would stand up to the work without giving trouble and requiring expensive care, and care is the most expensive commodity.

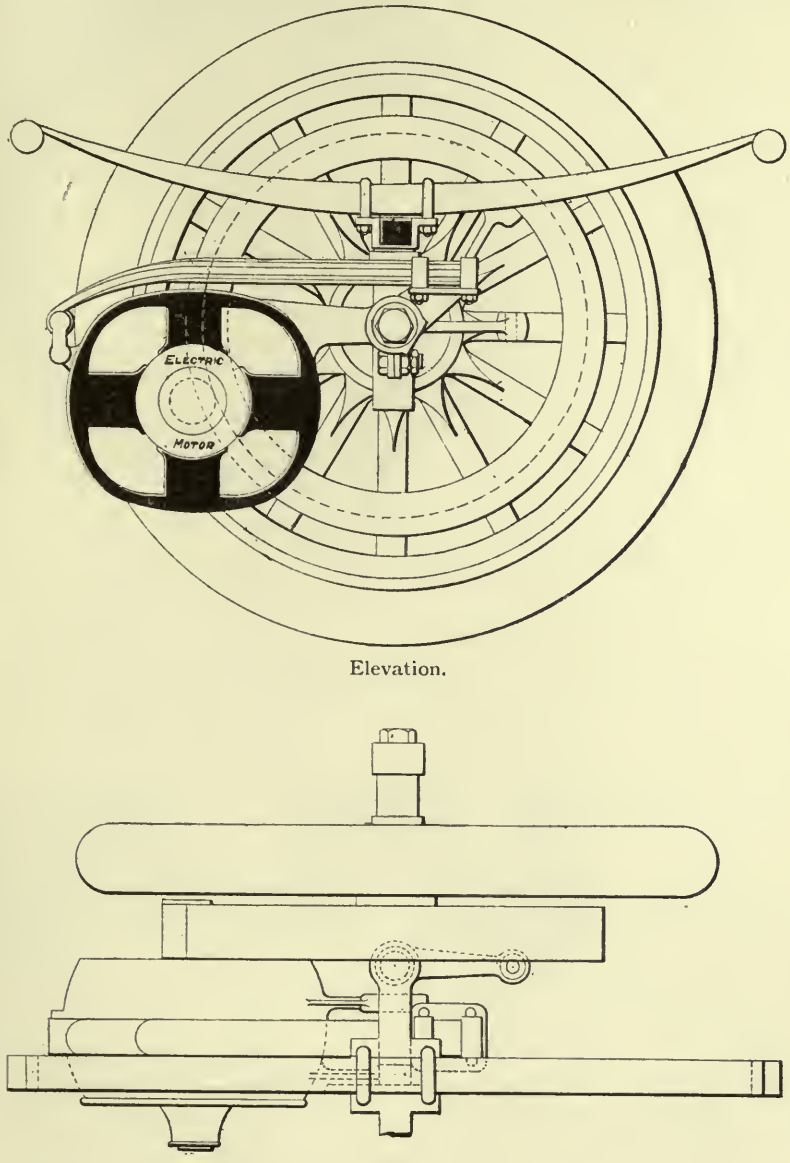
A somewhat similar cell has been brought out by a Swedish electrician, Professor Jungner.

The storage battery car is not a racing or sporting machine, but to any one who can afford to keep it in working order and purchase a good one in which durability comes in importance, before speed and weight, it offers advantages over all others. There is no offensive odour, no noise, no vibration; for easy comfortable motion, no vehicle, ether power or horse-driven, can excel it. For invalids or people who enjoy a drive in the country, and can keep such a car, it is a most satisfactory carriage. Many people cannot enjoy the pleasure of a drive in the country accompanied by the rattle of mechanism, puffing of an engine, and the oily smells. To those the electric car appeals, and it has some vogue.

About the best known electric cars in Paris, where many are in use by people who prefer comfort and quiet, are those of the Compagnie Parisienne des Voitures Electriques (Krieger system). The feature of this car is the employment of two electric motors connected one to each of the front road wheels, which are thus used both for driving and steering. The front axle has the form of a fixed cross bar. At the end of the bar is a pivot which turns a short axle carrying the road wheel. The electric motors are fixed to a support on the cross bar, and close to each of the front wheels. The motors drive the wheel by small pinions, which engage with large fibre gear wheels fixed to the road wheels. In this way each wheel is driven by its own motor, and electrically forms an independent system. One wheel may thus turn faster than the other, the use of a differential gear and its consequent mechanism being in this way obviated. The motors are of the 4-pole type; on one end of the outer casing of the same is cast a ring-shaped projection, which fits upon a collar on the journal. The motor is thus supported, and at the same time can take a certain angular displacement, which is, however, limited by a curved spring which holds up the free end of the motor (see Fig. 120). This method of supporting the motors greatly reduces the strain on the same when starting or stopping the vehicle. The motors, which are interchangeable and readily detachable, are entirely enclosed, so that no dust or dirt can get into the working parts. The battery of accumulators is divided into two groups, its capacity on one charge ranging from 40 to 50 miles, at an average speed of about 12 miles per hour. It consists of 44 cells, one half being located under the driver's seat and the other half under the rear seat. In the latest Krieger cars a battery known as the Phénix is being used. In this the electrodes do not consist of plates, but of vertical rods, the positive one being enclosed in porous pots. The arrangement is claimed to prevent disintegration of the active material, which remains

firmly connected with the contacts, notwithstanding any jolting or vibration caused by bad roads.

Among other claims made for the Phœnix accumulator are lightness, large surface, and a high ratio between the weight of the active material and that of the supports. They are also said to require much less attention in the way of cleaning out than the usual plate type. The 125-ampère hour cell comprises 42 electrodes, and weighs



Elevation.

Plan.

FIG. 120.—Krieger System, showing Method of Electric Motor Drive.

$23\frac{1}{5}$ lbs. The cell will give 2 volts, or say 250 watt-hours, multiplying the ampère hours by the volts; hence the capacity per lb. of battery will be $\frac{250}{23.5} = 10.7$ watt-hours per lb. of cell. And as a horse-power for five hours is equal to $746 \times 5 = 3730$ watt-

hours, we get $\frac{3730}{10.7} = 350$ lbs. nearly as the weight per horse-power for a five hours charge.

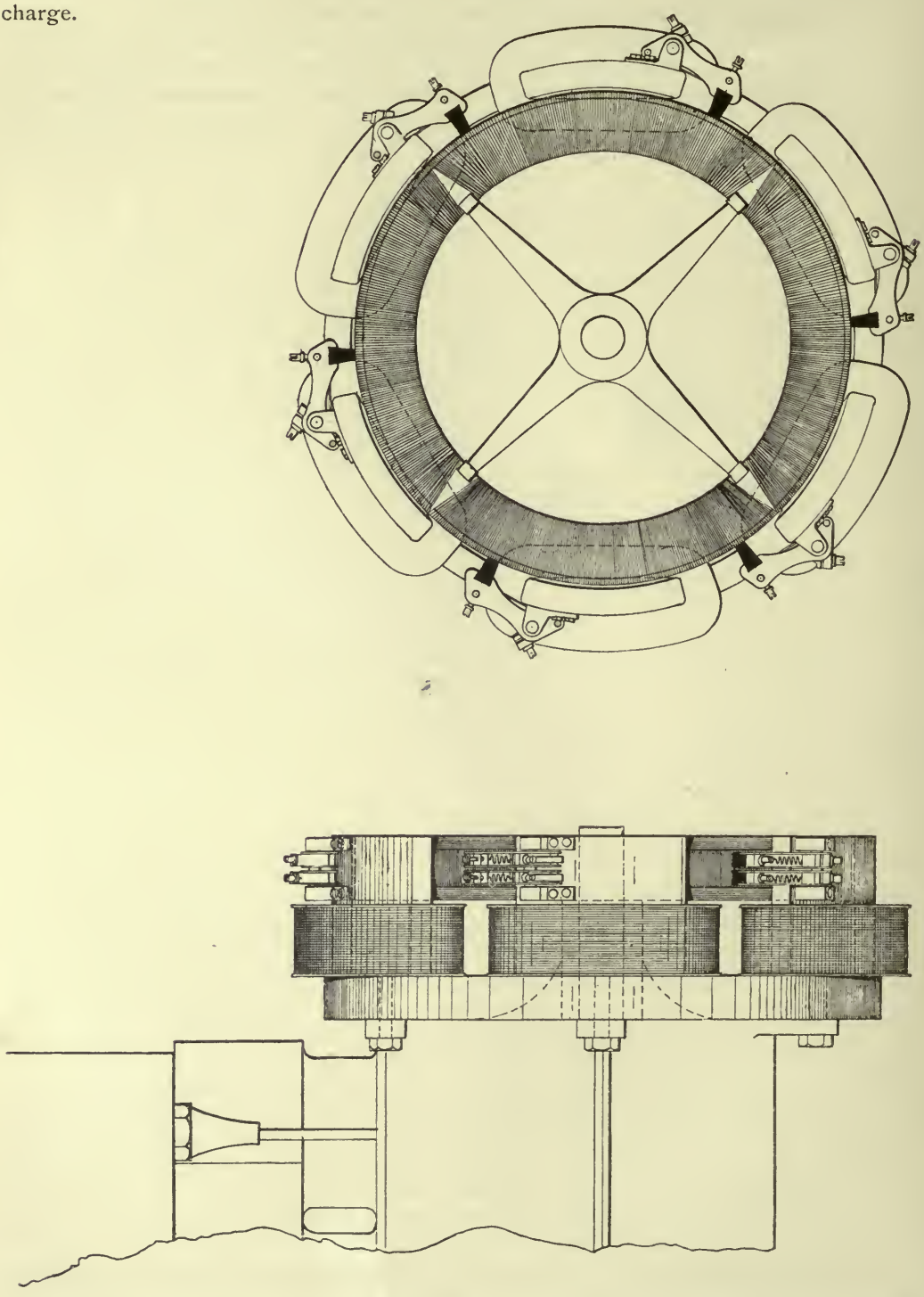


Fig. 121.—Elevation and End View of Dynamo for Electric Autocar.

The system using the petrol motor and dynamo on the car instead of the battery has been tried with indifferent success on road vehicles, but that has been due to the

obviously bad design of the combined machines and motors. To succeed, the dynamo designs and motors require very special knowledge and experience in the higher branches of electrical engineering, and further, the choice of a first class engine is necessary as the prime mover.

The following are the points which should be kept before the would-be designer of a good autocar driving by electric transmission gear. We cannot describe an actual good example, for it does not exist.

The engine should be of a speed moderate in revolutions per minute, and a piston speed of about 800 feet per minute, fitted with a good governor and low-pressure electric ignition (in autocar jargon, low *tension*). The dynamo armature should form the fly-wheel of the engine, and should be large in diameter and narrow axially, slotted, and gramme wound for an electric pressure of 30 volts at most. As the current has to be conveyed from one end of the car to the other, a distance only of a couple of yards, there is no reason whatever for a higher pressure, and this low pressure will compel the use of good heavy switches, fuses, cables, brushes, and other electrical fittings capable of standing up to the mechanical requirements, which the flimsy crockery fittings used for high electric pressure are totally unfitted for.

The field magnet should be multipolar, and have at least six poles arranged not radially but axially, and should consist of one casting of best high permeability steel. The commutator should be large in diameter, and of not less than 144 sections, if any commutator is used. These requirements refer to an 8 horse-power generator, at a speed of 800 revolutions per minute, 30 volts, 200 ampères, 6 polar, 6 kilowatts output.

The specific output is 0·0075 kilowatts per revolution. From this approximate dimensions of the armature may be obtained by formulæ in which

L = length of armature axially.	Ws = watts per revolution.
D = diameter of armature.	C = constant = 100.

To find D, calculate the circumference required to give the peripheral speed PS agreed upon, say 4800 feet per minute at the number of revolutions per minute; then circumference $= \frac{4800}{800} = 6$ feet. Then from a table of diameters we get D = 23 inches; Z, the magnetic flux total $= \sqrt{\text{K.W.}} \times 150 = \sqrt{6} \times 150$; hence $Z = 2.45 \times 150 = 366$ lines. There are three pairs of poles, each pair will carry 122 lines, and the armature between pole and pole will carry $\frac{366}{6} = 31$ lines of magnetic flux.

Nt—the number of turns on the armature—all round will require to be—

$$\text{Nt} = \frac{\text{V} \times \text{P} \times 10^6}{\text{Revolutions} \times \text{Z}} \text{ where V is volts.}$$

P = pairs of poles. Hence $\frac{30 \times 3 \times 10^6}{800 \times 366} = 300$ approximately.

By making the flux Z = 400 we can get a better division by using 288 conductors, 288 slots, and 288 teeth; 72 inches being the circumference of the armature, this will give $\frac{1}{8}$-inch slots and $\frac{1}{8}$-inch teeth, with one conductor in each slot. These conductors are connected, the front of one to the back end of the next; a gramme ring winding built up by a soft copper wire insulated inside the ring. Fig. 122 shows the various forms of conductors which may be used. The length of the armature is calculated to give a magnetic flux density in the air space at the polar faces of 7 lines per square inch. The total flux from each pole is $= \frac{400}{3} = 133$, so that as the poles cover 8 inches of arc of the circumference each, we will get the length by dividing

$$\frac{\text{Flux}}{\text{Density} \times \text{pole arc}} = \text{L.}$$

$L = \frac{133}{7 \times 8} = 2.4$ inches; to this must be added space occupied by insulating material between stampings, equal to about $\frac{1}{4} = .55 + 2.4$; 3 inches of stampings and insulations approximately.

For depth of slots we find that the conductors will each carry 33 ampères. A sectional area of .021 square inches will do this easily. And as the thickness of the conductors in the slots is $\frac{1}{16}$ inch, or 0.07, we get for breadth $\frac{.021}{.07} = 0.3$ inch; and adding $\frac{1}{10}$ inch for wear above slot, and $\frac{1}{10}$ inch for insulation at bottom of slot, we get depth of slot 0.4 inch, and breadth of conductor .4, or $\frac{3}{8}$ inch. The conductors are to be of hardest drawn copper, as their outer edges above the slots are to be used as collector bars and commutator, as shown in Figs. 122 and 123. Fig. 123 shows the collector bar A, held in place by the binding BB, and the insulation D. Fig. 124 shows another method in which the collector bars are extended and the projections *b* or *c* used as the commutator.

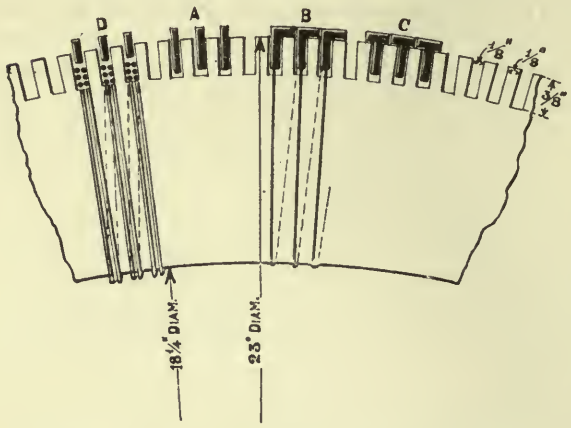


FIG. 122.—Section of Armature, showing Conductors or Collectors of Various Shapes.

The field magnet resembles a tube with gaps cut out to form six poles. The thickness of this tube and the armature may now be calculated. The flux through one pole is 133 lines, and this may be at a density of flux of 14 per square inch. Hence the square inches required $= \frac{133}{14} = 9\frac{1}{2}$, and as the length of arc of pole is 8 inches, the thickness must be $\frac{9.5}{8} = 1\frac{1}{4}$ inches as the required thickness of the pole tube.

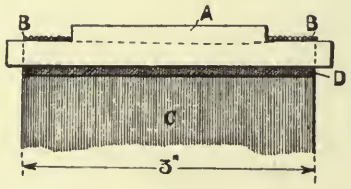


FIG. 123.—Armature Cross Section, showing Bindings and Insulation.

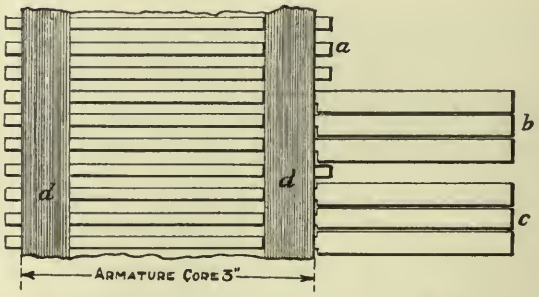


FIG. 124.—Plan of Armature, showing Method of extending Conductors for Collectors.

Similarly, we may calculate depth of armature stamping rings from bottom of slots to inner periphery; the length of ring is made up of iron equal to 2.4 inches if solid. This may carry 15 lines per square inch, and the lines to be carried are $\frac{133}{2} = 66$; hence $\frac{66}{15} = 4.4$ square inches required, and $\frac{4.4}{2.4} = 1.9$ inch, or 2 inches nearly, as this required depth. The slots are $\frac{3}{8}$-inch deep, so that if the outer periphery of the armature is 23

inches diameter, the inner periphery will be $23 - 2 \times 2 + \frac{3}{8}$ inch $= 18\frac{1}{4}$ inches. By this construction we avoid the use of the expensive commutator and all sparking troubles, and the armature takes the place of the fly-wheel, having a rim 3 inches broad and $2\frac{3}{8}$ thick carried on a cast-iron or brass spider. The field coils are 3 inches long over all, and each has 10 lbs. of No. 13 S.W.G. copper wire. The engine is bolted to the field magnet, with its shaft and fly-wheel armature concentric with the bore; and the brushes are carbon blocks pressed by springs between the poles. All negatives are connected in parallel and all positives in parallel. A thin slip of box wood or other hard wood is bound in between the projecting parts of the conductors on the armature.

The motors are designed on the same principles, only the field magnet may be double ended and have four poles, as the power of each is to be 3 kilowatts. Hence the diameter of armature will be smaller, and as I prefer a high speed motor with a back shaft for a single reduction gear, and to drive by chain on to the road wheels, the speed may be 1600 and peripheral speed 4800. Hence D will equal $\frac{4800}{1600} = 3 \times \frac{12}{11} = 11\frac{1}{2}$ inches. The current will be 100 ampères, or 25 ampères through each conductor. We will get 144 slots, same as before, $\frac{1}{8}$-inch wide with $\frac{1}{8}$-inch teeth between, on a circumference of 36 inches. A conductor of .012-inch sectional area will carry this current, and so if the conductor is again $\frac{1}{10}$-inch thick, or .07 inch, we get for breadth $\frac{.012}{.07} = .17$. Adding $\frac{1}{10}$ for wear, we get total breadth $= 0.27$, or say $\frac{5}{16}$ inch; and a slot $\frac{5}{16}$-inch deep with $\frac{1}{16}$ insulator at bottom will carry this conductor with $\frac{1}{16}$ inch projecting.

Z, the total flux, will be $= \sqrt{\text{K.W.}} \times 150 = \sqrt{3} \times 150 = 260$, and half this through each pole, or 130 lines. The poles may cover an arc of 6 inches on the periphery, with 3-inch gaps between poles. At a magnetic flux density of 7 lines per square inch on the polar face and a 6-inch arc of pole, we get a length of armature equal to $\frac{130}{6 \times 7} = 3.1$ inches; and for insulator, $3\frac{1}{2}$ inches may be taken as length axially.

The field magnets are cast in two pieces, to enable the coils to be put on or off, and there will be 8 coils on the field of No. 15 wire, about 6 lbs. on each coil all in series. $2\frac{1}{2}$ inches must be allowed for each bobbin of the field magnet.

The single reduction gearing is carried in lugs cast on the magnet casing. The thickness of the magnet tubes for the motors is found the same way as before. The flux to be carried is 130 lines, the breadth of the pole is 6 inches, the density of the flux 14 per square inch. Hence $\frac{130}{6 \times 14} =$ say $1\frac{5}{8}$ inch; and the depth of the armature will be found to be $1\frac{3}{8}$ inch; inside diameter, 8 inches. I have gone into this design numerically at some length, in order to show the dimensions of the electrical gearing as it should be. It will be observed that we have still some mechanical gearing; the single reduction wheel gears on the motors. This, however can be made noiseless by using a raw hide pinion, and being rigidly in one with the motor, is under very good condition for working with high efficiency and small care. The chain gear from the motors to the wheels presents no objectionable features.

Now, as to what we gain by electrical transmission in this case—

1st. We have no steering gear required,—steering and speed regulation and reversing are all performed promptly and with ease by a light switch.

2nd. No differential driving gear.

3rd. No speed gear or reversing gear.

4th. The motors and engine and dynamo can be carried either on the carriage springs or on separate springs, so that pneumatic tyres are not a necessity except at high speeds. At moderate speeds the ordinary steel springs will take the inequalities of the road without jar, as none of the machinery will be rigidly attached to the wheel axles or frames.

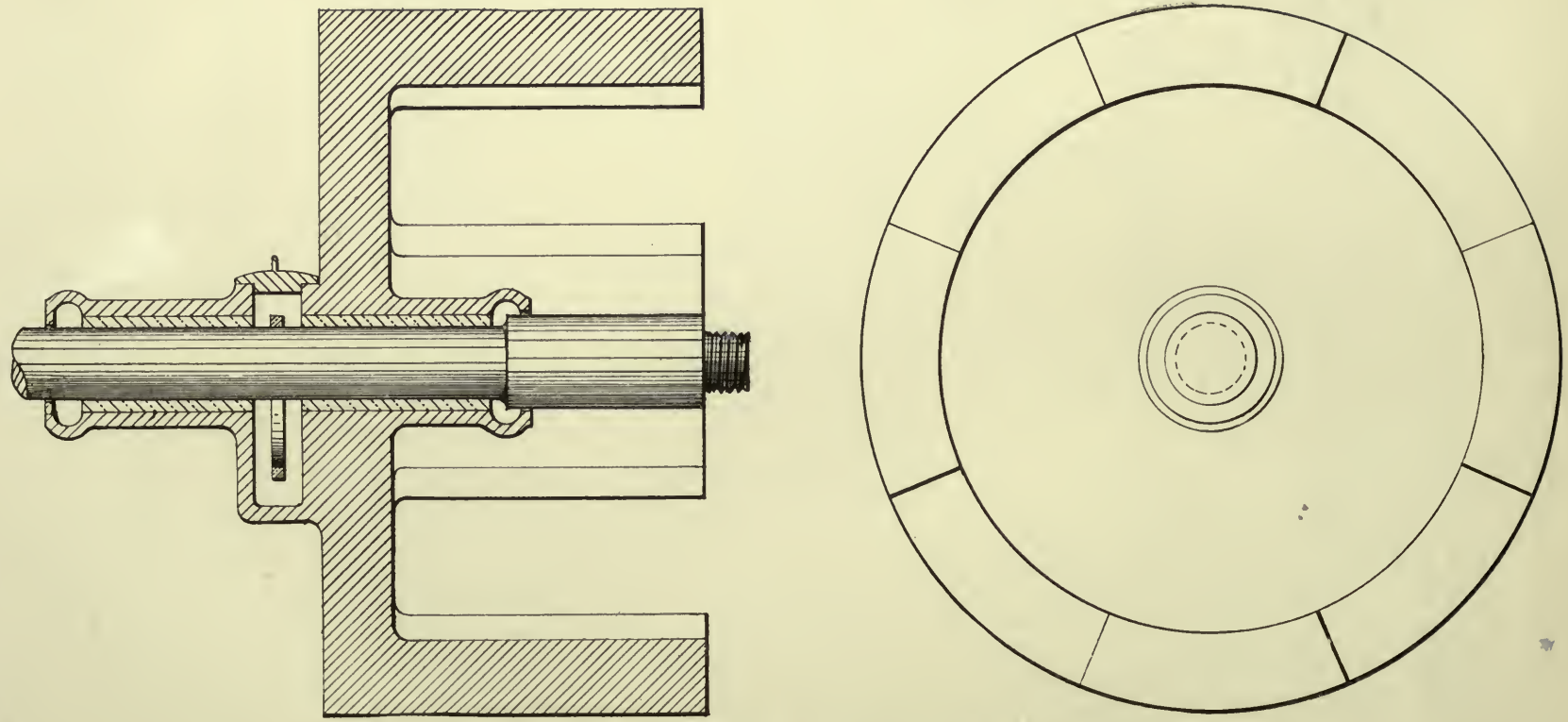


FIG. 125.—Sectional Elevation and End View of Field of Electric Motor for Electric Autocar.

5th. Pneumatic tyres may be used, in which case they will have a longer life ; for the spring mounting of the engine dynamo and motors will save them from much of the strains they are ordinarily subjected to.

6th. The engine can be started up without any mechanism or any handling, by means of a small accumulator of 6 plates giving 12 volts, used also for ignition and always kept charged by the dynamo while running. There is no necessity for keeping the engine running when the car is at rest. The ease of starting makes this unnecessary.

Eight horse-power is the normal power of this calculated electrical gear, but it will run to 12 horse-power if the engine will do it. Hence we have a seventh advantage, for by a switch weakening the dynamo field the speed of the engine may increase, giving the greater electric pressure and a greater current while the motors are going slower uphill, thus allowing the engines to do more work while the motors go slower.

In Fig. 121 is shown a side and end diagram of the dynamo and engine. And in Fig. 125 is shown a diagram of the motor field magnet.

The controller has a gearing switch, which has been often patented. The arrangement shown in Fig. 126 provides for the steering of motor cars in which two electric motors separately drive the wheels on opposite sides of the vehicle. This is effected by causing the wheels to revolve at different speeds. To this end the field coils a, a^1 of one motor are placed in series with the field coils b, b^1 of the other, and the two armatures d, e are connected in parallel, the switch arm h acting as one terminal for the complete motor circuit. By moving the arm h to right or left, resistances f, g are put in one or other of the two parallel branches of the armature circuit, thereby producing the desired differential action of the two motors.

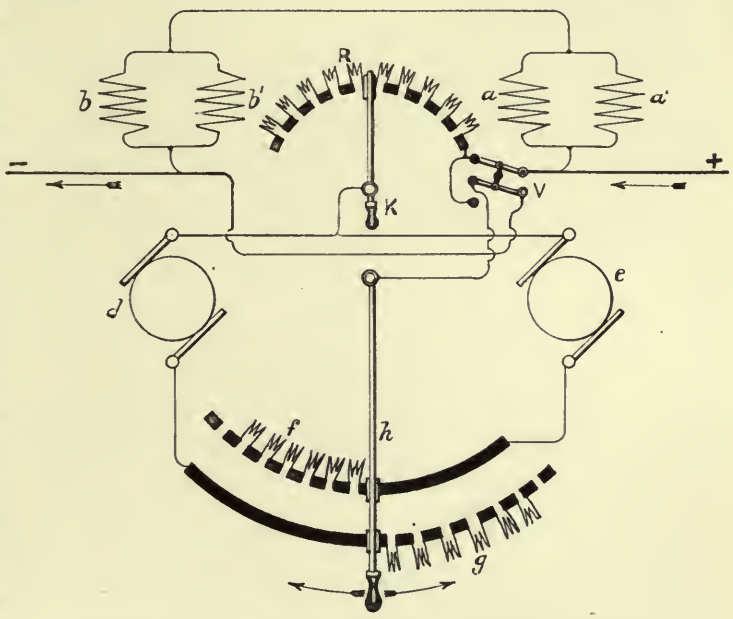


Fig. 126.—Diagram of Controller for Electric Autocar.

In addition to this arrangement there is a resistance R, which is variable by hand, so that by putting in more or less the speed can be varied. This simple device takes the place in the autocar of the noisy, expensive, and complicated, steering gear, reversing gear, speed gear, and differential gear required in mechanical transmission.

The reversing switch is shown at V. The three levers can be operated by one hand, h being in hand all the time. K, the speed handle, can be shifted into the speed notches, and V moved instantly into reverse by the same handle K.

As an example of the battery car, we may take the Electromobile Company's car shown in Figs. 127 and 128, in which the battery is slung underneath the car.

This system has been adopted to obtain (*a*) rapidly interchangeable batteries ; (*b*) even distribution of weight on the wheels ; (*c*) the collection of all the cells in a single box, to enable inspection to be thorough and manipulation simple ; (*d*) a low centre of gravity to minimise side-slip.

With the battery underslung any acid fumes escape at once to the air instead of destroying the woodwork and cushions, and affecting the atmosphere inside the carriage.

The wooden box containing the accumulator is braced by a light steel framework terminating in a lug at each corner. These lugs engage with strong taper pins sliding in brackets on the frame, which are operated from either side of the carriage by a simple screw mechanism.

In the depôt the accumulator box is lowered from its position by a hydraulic lift, and conveyed to the battery department for examination and charging, thus avoiding the damage to the carriage that might ensue were the battery always charged *in situ*. At the same time, the carriage, freed from the batteries with the charging cable, can be taken to any part of the depôt to be washed, or for the motor and gearing to be examined or repaired without any risk to the attendant from electric shock. The chassis and battery box together weigh 9½ cwts.

FIG. 127.—Electrically Driven Cab.

The Battery consists of 44 "Contal" cells of a special pasted type, and weighs about 10 cwts. Its capacity is 135 ampère hours, and affords sufficient power to propel the Victoria about 40 miles over average roads in fair condition.

Each plate is formed of two thin grids of antimoniated lead, riveted together, and presenting thirty-two square holes for the active material, compressed into the grids by means of an hydraulic press, which rivets the plates and perforates each pellet of active material with nine holes. Experience has shown their durability to be commercially satisfactory, the positive plates having a life of from twelve months, according to the work done. The plates of the battery are of small cost, and very easily replaced.

The Motor.—This is of 8 brake horse-power, at 1500 revolutions, on a continuous load, but it can safely exert over 16 horse-power for short periods. It is of the ironclad type, bi-polar, and series-wound, having two separate commutators connected to separate armature windings. The designers, MM. Contal and Gasnier, have introduced a very compact arrangement of field castings and bobbins, by which magnetic joints are avoided, and the distortion of field due to armature reaction is counteracted, resulting in a reduction of field ampère turns and a total suppression of sparking. The field casting forms a protective shell, enabling the motor to be completely enclosed, but at the same time rapidly dismantled. Doors of ample size give complete access to the commutators and brushes, so that adjustment of pressure is easy. The carbon brushes are of the type successfully adopted for many years by Messrs. Greenwood & Batley for their small motors.

Transmission.—The motor drives through a double train of double helical gearing to the differential, and thence to the hubs of the rear wheels by live shafts, which revolve in an external tubular axle. This axle is stationary, except for the slight radial movement permitted by the suspension springs carrying the motor.

It consists of two tubes united by a cast-steel gear box, and extending within the road wheel hubs, which revolve upon them. Thus the internal driving shafts are relieved of all bending stress, and are in simple torsion. Their outer ends are a sliding fit in an hexagonal hole in the hubs, so that the road wheels can be removed as easily as ordinary carriage wheels, an advantage not easily secured when part of the driving gear

itself is mounted on the road wheels, as is often the case. The motor casing is continued into the gear box, so that the entire driving mechanism is dust and waterproof, and can be entirely detached from the carriage by removing the spring clips and the pin by which the motor is suspended from the frame. The gear runs in oil, which is thereby circulated automatically through the bearings, and can only escape after reaching the road wheel hubs.

The Controller gives forward speeds ranging from three to fifteen miles an hour, two electric brakes, and one reverse speed. It is simple and remarkably compact, owing to the arrangement by which alternate brushes are attached to opposite rows of terminals.

The framework of the controller is an aluminium casting, bolted direct to two longitudinal angles of the chassis, which also carry the steering bracket. Its position

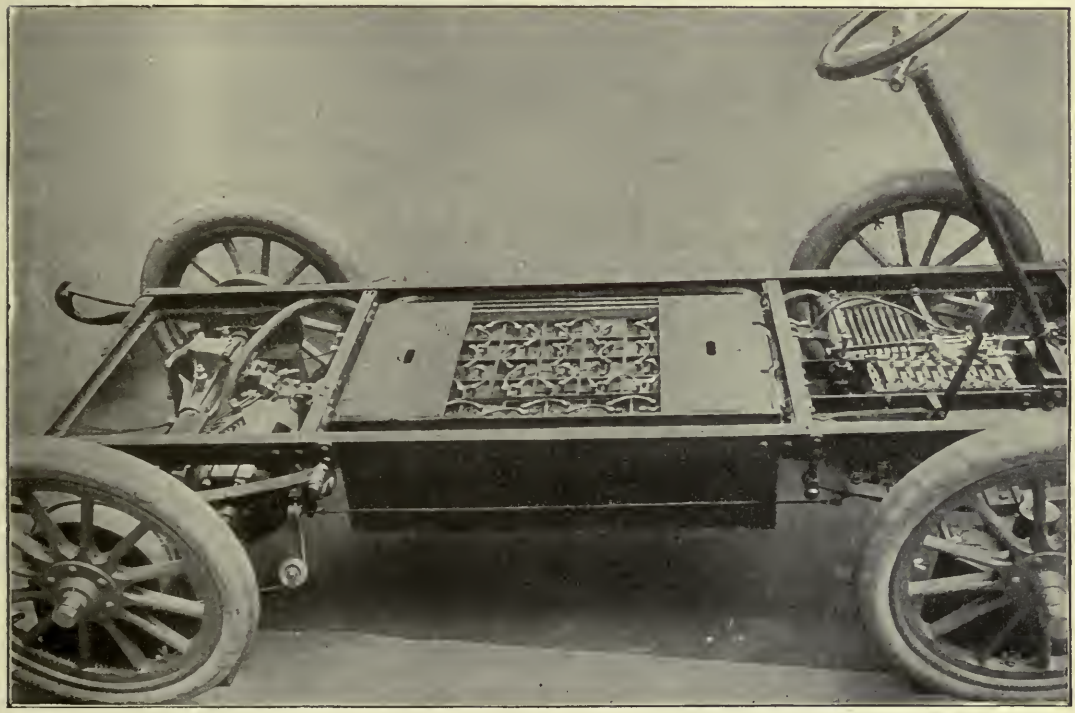


FIG. 128.—View of Electric Autocar Chassis, showing Battery in Position.

is thus horizontal, and immediately below the floor boards, in which is a trap-door exposing the brushes and terminals. It is enclosed from below by a sheet metal casing, carried across the frame so as to protect all the electrical fittings from mud and wet.

The handle actuating the controller is immediately below the steering wheel, and moves in a plane parallel to the wheel. This has been found in practice to be the most convenient position, as it necessitates the least movement on the part of the driver. The handle is mounted on a tube concentric with the steering spindle, which actuates the controller by means of bevel gear. The usual ratchet mechanism is provided to prevent any lingering between the positions of contact. An index plate showing the positions for the speeds is mounted immediately below the controller handle on an external tube, which renders the whole steering column rigid.

CHAPTER V

PETROL MOTOR BOATS

These have been frequently referred to already without going into details.

Of motor boats in general a good deal of unreliable information is to be had, and very little vouched for by any independent engineers. The talk about horse-powers cannot be taken as accurate in any sense. No engineer could doubt for a moment that a petrol motor could be fitted into a boat and propel the boat with a speed proportional to the power, even if the engine had only one cylinder, and it would not require the expenditure of much time, thought, or money to find out that two, three, four or six, or any number of cylinders could be added; it would be harder to account for the added cylinders in many cases.

The drawbacks to the internal combustion engine on a boat are the same as those on a car with reversing gear, starting gear and speed gear all necessary, as we have already shown in Volume II.

For sport and pleasure, petrol boats have some vogue at present, but the practical results do not seem to lead to anything of much value in promoting the internal combustion engine for real commercial purposes. In the shipping trade for cargoes, or passengers, the space inside the vessel cannot be occupied entirely by engines and machinery, and the cost per ton mile or per day at full speed is an important item, so that the facts proved by sporting tests, as they have no bearing on the important points, are of little scientific interest; they merely confirm what we all know, that it is possible to drive a boat at a high rate of speed by a sufficiently powerful engine. It may be that these tests may result in better designs for the hull of a small boat, that is another matter. To make any tests conclusive and of value requires rational methods; racing one boat against another proves nothing, or very little. A poorly made hull may win with a powerful engine; on the other hand, a weak engine may win in a finely made hull. To test a boat by racing against another is popular, spectacular, and all that, and has its educational uses in familiarising the public with petrol propulsion; but as a substitute for scientific tests it can never be accepted. To ascertain the true qualities of a boat, the engine tests and the sailing properties of the hull must be carefully ascertained separately, and not by any empirical means, but by rigid scientific tests. This, of course, is never done; instead of facts we get assertions, and instead of tests and their results we get the results of a race in which circumstances and chance play no small part.

The real problems connected with the marine internal combustion engine have not hitherto been touched upon; they are many and difficult of solution. The hoisting of a motor car engine aboard a boat does not go far towards a solution of the difficulties. Be that as it may, it is of interest to note what has really been done with petrol boats, in which no attempts are made to solve difficulties, but merely to adopt the petrol motor and its necessary gear to small boat propulsion for short runs regardless of expense.

THE TWO-CYCLE ENGINE

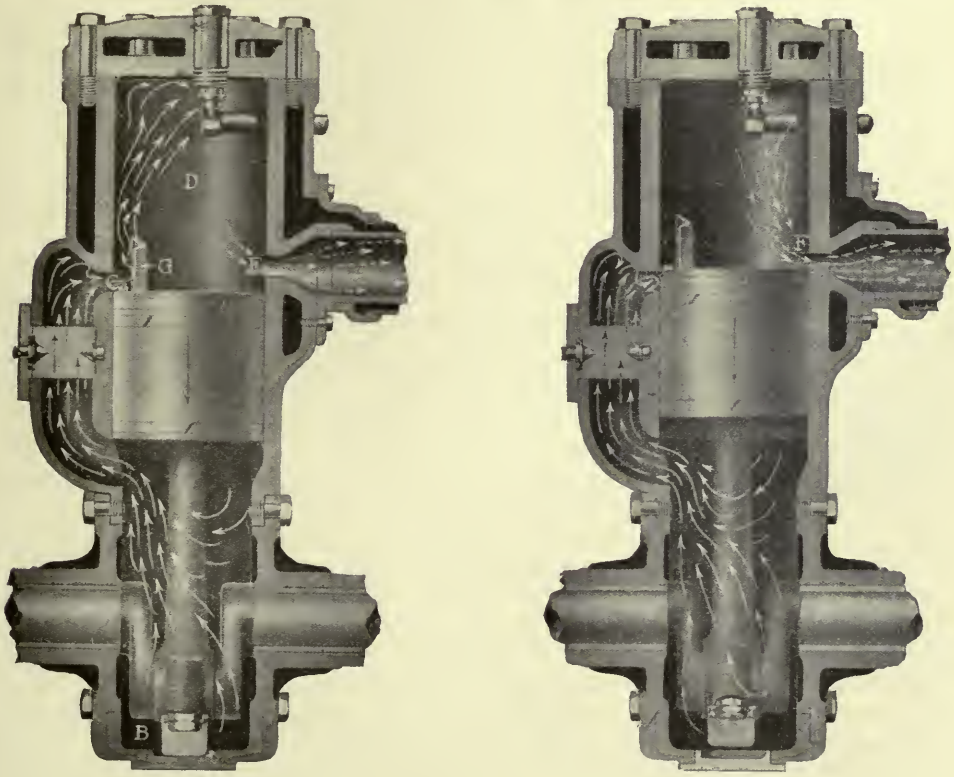
This engine has been fully treated in Volume II. Its simplicity and few parts hitherto recommend it for small powers, and it has been largely introduced by American makers with reversible propellors and a clutch. In its simplest form the crank case receives the mixture in the up-stroke of the piston ; in the down-stroke the mixture is compressed slightly in the crank case, so that if there is any slack about the bearings or other places the mixture tends to leak out. At the end of the down-stroke the piston uncovers the exhaust ports and the mixture inlet port, so that the fresh charge drives out the exhaust.

An improved type has been described in the Glover and other engines (Volume II.), in which the crank case is open and the charge *drawn* in after the exhaust, which is *drawn* out. This principle of working removes the chief drawbacks, and provides an engine superior to the 4-cycle engine, as with only two cylinders and two cranks opposite two impulses per revolution are obtained with an engine of very simple construction.

THE LOZIER SMALL MARINE OIL ENGINE

This type of engine has already been referred to, and will now be fully described in its operations, as a very large number of this class of engine are applied to ships' launches and other small-boat propulsion.

In operation a charge of petrol and air is drawn from a carburreter into the



Induction. Exhaust.

FIG. 129.—Lozier Marine Motor.

crank case B ; on the down-stroke of the piston a check valve on the vaporiser closes, and the mixed air and petrol is compressed slightly. At the completion of the down-stroke the exhaust port is opened slightly before the inlet port, the exhaust escapes, and

the mixture in the crank case expands into the cylinder, through C (Fig. 129), and is deflected upwards; the up-stroke compresses the mixture, and it is fired at the end of the up-stroke, giving an impulse to the engine. This cycle is repeated. Referring to Fig. 129, the piston when near the down-stroke end uncovers the exhaust port F, and then uncovers C, the inlet continues slightly open, until the bypass opening C, which is situated exactly opposite but a little lower than the exhaust port, is uncovered, admitting a fresh charge of gas from the crank base into the firing chamber D above the piston. This new supply or charge of fresh gas is deflected into the upper part of the cylinder or firing chamber by a defector or baffle plate G (Fig. 129), which is fastened to the top of the piston. This deflector is intended merely to prevent the incoming charge of fresh gas from travelling directly across the firing chamber and escaping through the exhaust port F, nearly opposite. The up-stroke of the piston then commences, owing to the impetus given the fly-wheel on the down-stroke, or during the explosive period, compressing the new charge of gas in the firing chamber D and at the same time again drawing a new supply charge from the vaporiser inlet A into the crank base chamber B. Admission and exhaust are thus controlled by the piston movement alone, the engine itself being valveless.

The down-stroke of the piston is caused by the expansion, or as it is commonly termed explosion, of the gas in the firing chamber, and this down-stroke may therefore be referred to as the explosive stroke. The up-stroke of the piston is caused entirely by the momentum which the fly-wheel gains during the explosive stroke, and the up-stroke of the piston may therefore be called the recovery stroke.

Fig. 130.—Throttle Valve.

An improperly designed gas engine may cause considerable trouble by what are known as "back explosions." The most fruitful source of back explosions is found in engines which do not allow the ignited gas of one charge to completely escape through the exhaust before the fresh supply is admitted. It will be noted in Fig. 129 that the exhaust port F is opened and the burnt gases allowed to escape before the charge of fresh gas is admitted to the firing chamber through the by-pass opposite. It can be seen that if fresh gas were admitted at the period indicated by Fig. 129 the fresh gas might mingle with the escaping gases at F, and if the flame of the escaping gases were not entirely extinguished or burnt out it would ignite the fresh gas and cause a premature explosion, preventing the piston from taking the recovery stroke.

Another matter frequently overlooked by inexperienced builders is the possibility of premature ignition through heated projections in the firing chamber. Inasmuch as the explosions follow each other in rapid succession any small metal projection in the firing chamber would within a few moments' time become very heated and sufficiently hot and incandescent to ignite the fresh charge of gas before the piston was in proper position to receive the explosion, and a "back explosion" would result. The baffle-plate G is kept comparatively cool by the inrush of fresh gas at each stroke. The two other parts are the firing plug in the cylinder head and the rocker arm which passes through the cylinder walls. It will be noted that both the firing plug and the rocker arm are practically surrounded by the circulation of water, which keeps these parts comparatively cool and prevents overheating.

There is a wing valve in the inlet passage whereby the supply of explosive mixture can be controlled and the engine speed regulated accordingly.

Much of the difficulty encountered in the operation of petrol engines has been in reducing the speed. In most engines reduction of speed is attempted by changing the

amount of gasoline or air by means of separate valves. By this method the explosive quality of the gas is altered, and the engine frequently and unexpectedly comes to a sudden stop. An attempt to regulate speed in this manner is always attended with unsatisfactory results.

The speed of this engine can be easily controlled by simply turning the throttle valve (Fig. 130) which controls the flow of gas after it has been properly mixed in the vaporiser. By this method the quantity of gas is diminished, but its explosive quality is in no manner changed.

Petrol will form into vapour much more readily if combined with dry air, and a mixture of dry gas will ignite much more readily than will a mixture with cold, damp air. The vaporiser is supplied with dry air only. The galvanised iron cylinder or jacket A (Fig. 131) surrounding the muffler B forms an air-drying chamber, the dry air being fed to the carburetter through the pipe C. In extremely wet and foggy weather the holes in the vaporiser air supply pipe can be covered by the sliding sleeve D, and all the air for the vaporiser will then be drawn from the dry-air jacket. Some engines that run quite well in dry weather will absolutely refuse to work in fogs or rain, but with the air-drying jacket the engine will run steadily and continuously under all conditions of the weather.

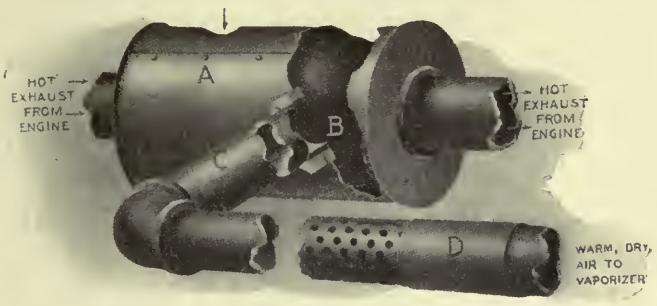


FIG. 131.—Exhaust Muffler.

THE FOUR-CYCLE ENGINE

This engine, owing to its being in the height of fashion just at present in autocar circles, has been adopted for the larger of petrol boats. On a motor car, where cold water is not superabundant, it has the advantage of requiring less cooling; there being only one explosion in two revolutions, the exhaust being swept out and a cold charge drawn in, in the intervals there is more time for heat being carried away. It requires a fairly heavy fly-wheel to maintain the speed between the explosions and compressions of the charges.

NAPIER FOUR-CYCLE ENGINES

These engines are used on the Napier cars and motor boats. The general elements of design are that the motor is of the vertical type of petrol engine, running on the Otto cycle. The cranks are set at an angle of 180° for the four cylinders, so that two explosions or working strokes are secured at each revolution. The valves are either of the automatic type or are mechanically operated for admission, in the latter case being worked from one cam shaft, as shown in the illustrations, Fig. 132 being a sectional elevation and Fig. 133 a sectional end view. The exhaust and admission valves are on the same side of the cylinder, the latter being above the exhaust, as shown in Fig. 133. This arrangement allows of the explosive mixture as it comes in cooling the exhaust valve as it passes over the latter. This has been found to give considerable durability to the valve. In order to slow the engine there is a throttle on the carburetter. A device recently introduced is an automatic valve on the air supply, this being actuated by means of the water circulation. As the engine gains speed the water pump, which is driven from the main engines, runs faster, and the pressure in the

water-cooling system is thus raised. The auxiliary air-supply mechanism is worked by means of a flexible diaphragm, on which the water presses. The automatic admission valves are actuated in the ordinary way. The exhaust valves are of the mushroom type, and are worked from the cam shaft in accordance with usual practice. The inlet valves are worked by the inclined rod shown in Fig. 133, by means of the gear indicated.

The water jacket for the cylinders is, in the smaller powers, cast in one with the cyclinders. In the larger type the jacket is of aluminium, the liner being of cast iron. The latter is made almost to the same size as the hole it is to fit into, being forced in by means of a power press. This gives a perfectly tight joint, it being found in practice that no leakage occurs. Contraction and expansion due to the heating and cooling of the metal are provided for by the aluminium casing being kept cool by the water within the jacket The exhaust valve also is water-jacketed. The pistons are of cast iron,

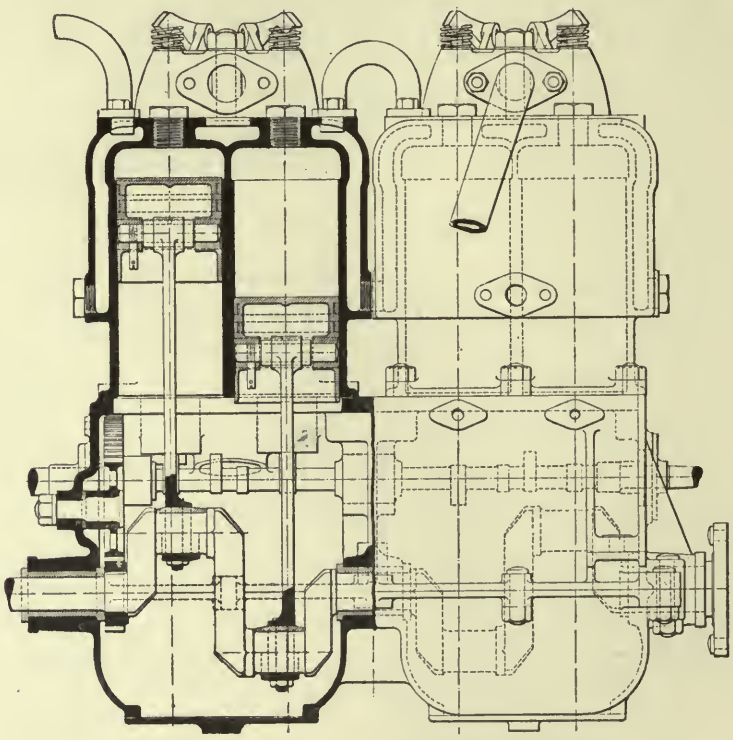


FIG. 132.—Sectional Elevation of Napier Engine.

with steel rings. The connecting rods are made out of steel stampings, or are of hollow circular or tube section in the larger size engines. The bearings are of gun-metal, and in the higher power engines are babbitted. The oil base, which is the foundation of the engine, is an aluminium casting, and is bolted to the engine body, the latter being also of aluminium, the two thus forming the crank chamber. The latter has brackets or feet by which the engine is bolted to the vehicle or boat. The half-speed shaft, which constitutes the cam shaft to operate the valves, is driven from the crank shaft by spur gearing.

The carburetter is on the jet principle, and is of the usual form, with float chamber and a gauze strainer for the petrol. There is an auxiliary regulator for the air supply within reach of the driver, it being fitted on the dashboard. This is the only part that needs attention, owing to the change in atmospheric conditions or temperature. The accelerator is worked by a pedal, which cuts out the governor and prevents the throttling of the mixture when the engine gains speed. The governor is fitted on

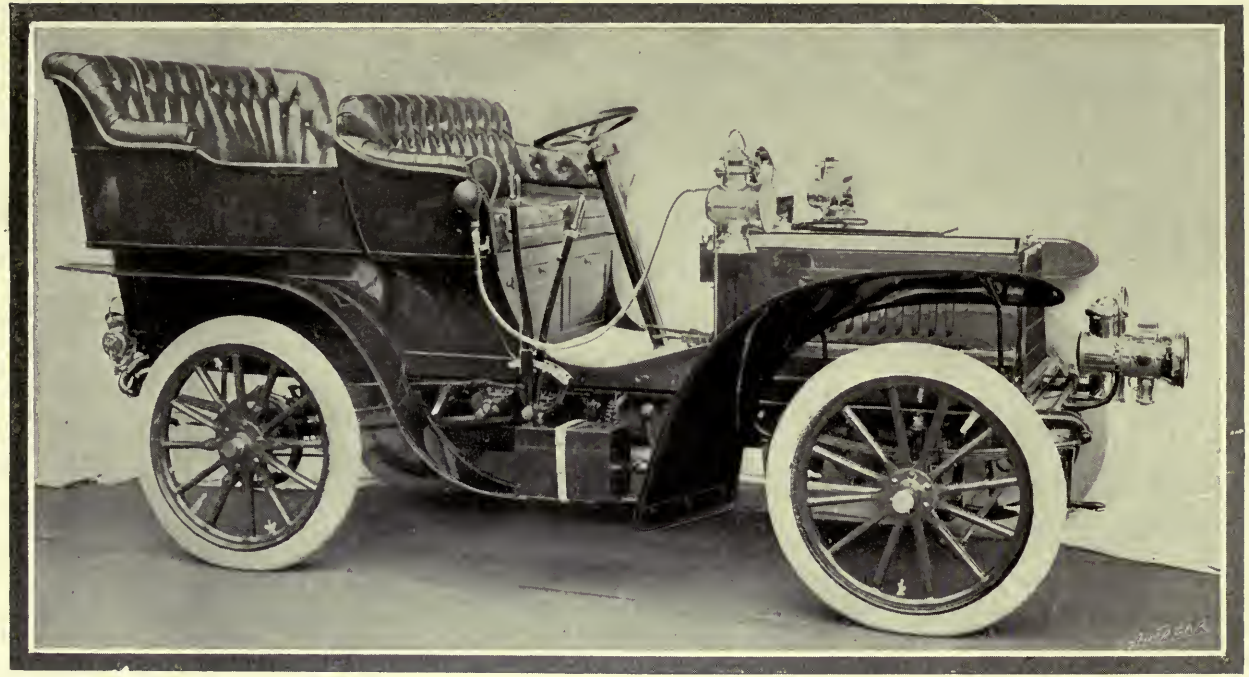


PLATE IV.—PARAFFIN AUTOCAR.

the cam shaft, and thus runs at half the speed of the crank shaft. It is of the ordinary centrifugal type, controlled by springs, and operates on the throttle by suitable lever connections. The crank shaft is a solid steel forging. In autocars power is conveyed to the cross shaft carrying the sprocket by means of the clutch and gear. The standard clutch consists of an aluminium cone, leather-faced, which fits inside the cast-iron fly-wheel. There are three or four powerful spiral springs, which keep the friction surfaces in contact under normal conditions of running. The clutch is released by pressing on a pedal. In order to take the end pressure at the moment of releasing the clutch there is a ball race; when freely running there is, of course, no end thrust.

The flexibility claimed for this engine is a notable feature, a range of speed from 150 to 1500 revolutions being considered practicable; the maximum brake horse-power being somewhat over 80. The weight of the engine complete with all gear is 1045 lbs. If, however, aluminium were used in place of cast iron, it would weigh no more than 650 lbs. The objection to the lighter metal is that it is quickly corroded by the action of salt water. No electrolytic process has been devised for coating aluminium with incorrodible metal.

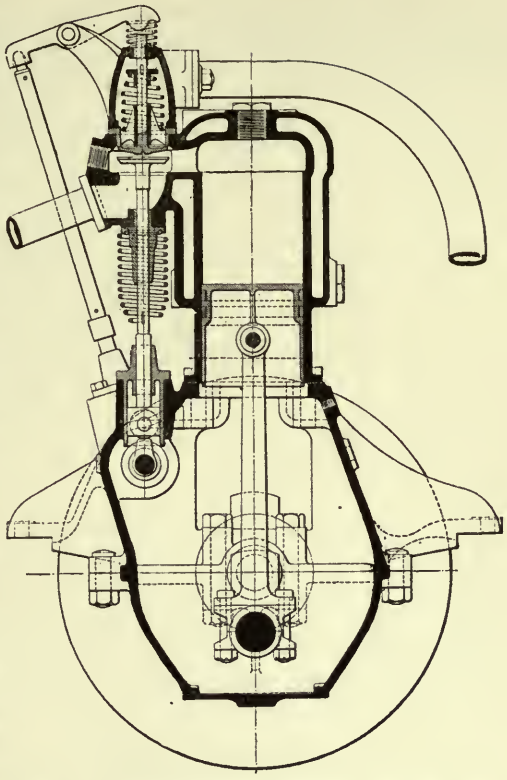


FIG. 133.—Sectional End View of Napier Engine.

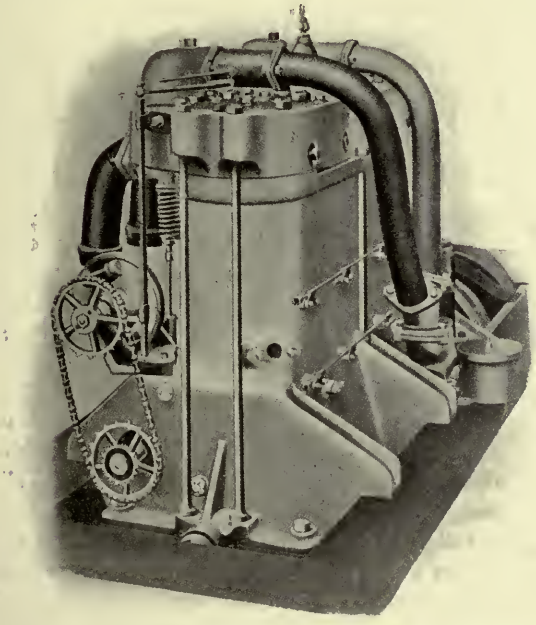


FIG. 134.—Napier 2-Cylinder Marine Motor Complete.

The change-speed gear, which is illustrated in Fig. 135, gives four different speeds forward and one reverse. The change is effected by sliding the gear wheels, and the speeds vary from four miles up to fifty miles an hour under favourable conditions on the level. It may be mentioned, however, that it has been contemplated to do away with change speeds, and to work only on the engine. In a new design of car which is being constructed there are three speeds; the top speed driving direct, and operated by a clutch. All gear wheels are of hardened steel and machine cut. The gear box is of aluminium.

The method of regulating the air supply to the carburetter is by hydraulic means as introduced by Messrs. Napier. Advantage is taken of the higher pressure in the water

circulation when the engine is running fast,—this higher pressure resulting from the increased speed of the pump, and the augmented friction of the water through the

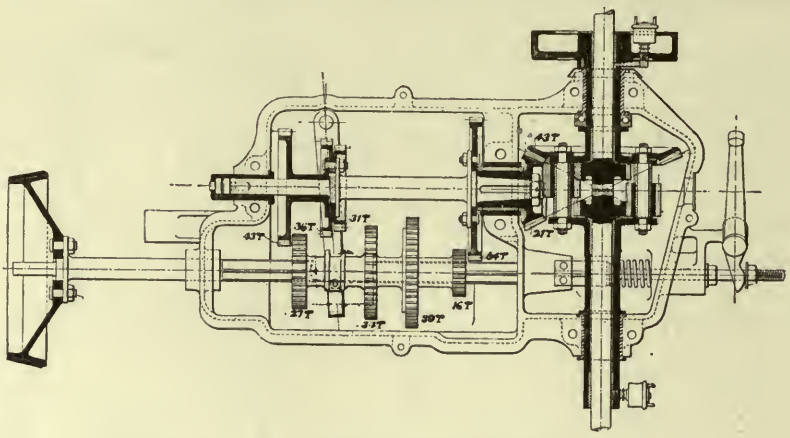


FIG. 135.—Sectional Plan of Napier Change-Speed Gear.

jackets,—to actuate the valve B in section in Fig. 136, the air admission branch being shown at A. There is a diaphragm C contained within the vessel as shown, and this is connected to the valve B by the stem. The valve stem is surrounded by a spiral spring, which under ordinary conditions of running keeps the valve in the position indicated. When, however, the water pressure rises it overcomes the resistance of the spring to a certain amount, and thus forces the valve down to the position shown by the dotted lines; this allows more air to pass, as is required when the engine is running at higher power. The arrangement of carburetter is shown and plan in section in Fig. 136. The device, as will be seen, is extremely simple, and is found to be of great advantage in running.

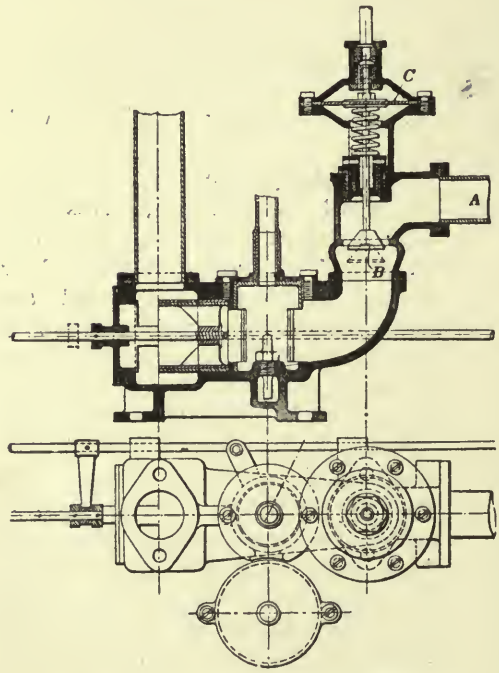


FIG. 136.—Sectional Elevation and Plan of Napier Carburetter.

Mr. S. F. Edge, of the Napier Company, has made some tests on various shapes of boat hulls, the results of which are of considerable interest to boat builders. And Mr. Edge and the Napier Company have contributed very considerably to the progress of petrol marine engineering by their high class designs and workmanship and energetic enterprise.

The petrol boat for small powers has advantages over the steam boat. Small boilers are a considerable source of trouble, and require much skilled attention. Well-designed petrol boats, in which every care is taken against fire risks, and in which the engine and gear are reduced to their simplest parts of ample strength, are successful as ships' launches and for pleasure sailing in safe waters.

A few have been made of large powers—about 100 horse-power or so, but it is very

doubtful if they could compete in any sense with steam of same power. Petrol is a product of American petroleum, and can therefore be had plentifully in that country. Hence petrol boats have made more progress, so far as numbers in use are concerned. In this country we have to depend on foreign supplies, and these will increase in price.

The situation would be entirely changed if alcohol could be obtained at its true value untaxed for motor purposes. The internal combustion motor industry of all classes should combine on this question. They may be a small minority, but aided by the chemical fraternity, who are also handicapped by the restrictions on alcohol in industrial processes, they might make an impression on the body politic.

The motor car and small motor boat would greatly benefit by a cheap supply of alcoholic fuel.

The difficulty with boats is in some cases not so great, as boats may be used outside of the area of taxation with cheap foreign spirit.

The points of interest connected with alcohol as a fuel compared with petrol are worth referring to again. First, the engine requires to be worked at higher compression and greater expansion, that is a longer stroke. The result is a much greater expansion, as it gives a gradual pressure curve.

By weight 3 lbs. of petrol give as much power as 4 lbs. of alcohol, and if the alcohol is not adulterated by solids it leaves nothing behind it of a harmful nature.

Alcohol is a nicer liquid to deal with, and if it is fired water will extinguish it. Water will not extinguish a petrol flame. A few drops of petrol on a glass of water can be fixed. But a considerable amount of alcohol can be poured upon water before it becomes imflammable. Altogether, apart from the benefits to the landed interests in substituting a fuel grown annually on the farms, and the industrial operations in the manufacture of alcohol, there is a prospective benefit, inasmuch as it would prepare us for the days when coal will not be so plentiful and cheap as it is now. Everything therefore points to the desirability of liberating this liquid fuel from its present restricted uses.

ALCOHOL VAPORISER

The accompanying illustration (Fig. 137) gives a sectional view of the Brouhot vaporiser, which is composed essentially of two parts—the distributor D and the vaporising chamber H. The object of the distributor is to regulate the quantity of alcohol exactly to the requirements of the engine. In this positive feed chamber is a vertical stem terminating at its lower extremity in a cavity, of which the capacity is regulated by the thumb screw, on which rests a tappet of the exhaust valve. This cavity is in communication with the constant level chamber. The admission of alcohol is effected by means of the exhaust stem A, terminating at its lower end in a nut G.

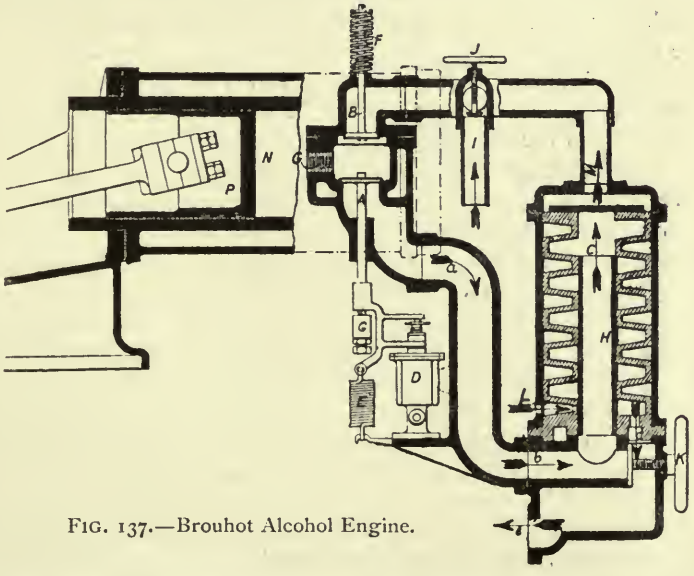


Fig. 137.—Brouhot Alcohol Engine.

As the exhaust valve opens, the nut raises the forked tappet, which is normally kept

down by the spring E. The forked piece then raises the stem, when the alcohol in the cavity is drawn into the distributor. On the exhaust valve descending the upper tappet strikes the top of the stem, which closes the cavity, and puts the bottom part into communication with the constant level chamber for another supply of spirit. Thus at the moment of each suction stroke the exact quantity of alcohol is admitted into the distributor for a full charge. On entering the vaporiser H, with a certain proportion of air, the alcohol is pulverised by the suction stroke. The vaporiser is composed of two concentric tubes, between which is a sort of double spiral chamber, through one of which passes the carburetted air, entering at L, and circulating upwards, and through the other pass the burnt gases, which rise up the central tube and return by the spiral chamber, finally leaving by the exhaust pipe at *e*. During its passage up the vaporiser the alcohol continues to be pulverised, and is in constant contact with the walls of the spiral chamber, through which circulate the burnt gases. By the time it reaches the top of the vaporiser the alcohol is in the form of a hot vapour mixed with insufficient air for combustion ; it then passes through regulating valve G, and with additional air drawn into the cylinder through inlet valve B.

Some of the paraffin oil vaporisers can be used for alcohol vaporisers. For those who wish to try alcohol on motor boats this model will give a fair idea of the requirements.

HORSE-POWER

Hitherto engineers have used the foot-lb. per second or per minute,—33,000 foot-lbs. per minute as a horse-power, the watt (=44.2 foot-lbs. per minute), the kilowatt, the C.G.S., the kilogrammetre, and have found these units ample for all purposes.

The ancients used a unit called a nominal horse-power. Its origin is obscure, and its meaning more so. The Marine Motor Association have introduced a somewhat similar arbitrary unit called a "motor-power,"—M.P. for short. It is to be hoped it will never become common in use. Such meaningless terms only lead to confusion. There is only one set of units admissible in engineering, those based on the laws of nature ; and engines can only be rated at the accepted horse-powers each of 33,000 foot-lbs. per minute on the brake.

At the present day there is no difficulty in, and no excuse for neglecting, scientific brake tests of any engine whatever, at any speed, to get an accurate measure of its brake horse-power (B.H.P.), and that is the power of the engine for the actual work to be done.

The indicated horse-power (I.H.P.) is of interest scientifically only, to enable the test to show the power wasted in the engine itself, to demonstrate the action of the valves, and the rise and fall of pressures in the engine cylinders.

The motor horse (M.P.) can only be a rough approximation to the brake horse, and is arrived at by calculations made from the cylinder dimensions and number of revolutions per minute, 800 being taken as a standard speed. It, however, ignores the fact that there is a considerable variation in the difference between I.H.P. and B.H.P. in engines built from same patterns and run at same speed.

The testing of petrol engines is an easy matter, and every respectable maker should have a testing apparatus. It consists of a dynamo-electric machine, or two, in which the losses are constant and known at various loads and speeds ; it is only necessary to couple the engine to be tested to the dynamo and adjust the speed to the desired value, switch on large incandescent lamps for a load, and when all is running steadily measure the fuel consumed per hour, take speeds, read volt meter and ammeter or a watt meter, take indicator cards, temperatures, and other notes. By doing this an accurate knowledge of the engine can be ascertained. Any desired load may thus be put on and kept constant, and is easily measured.

A prony brake might be used for power tests, but at high speeds it requires

lubrication, and is altogether a messy and untidy job to tackle. The dynamo is a beautiful brake, which runs quiet, cool, and cleanly, and the load can be varied and read off with the utmost ease and accuracy.

It would be very interesting to get half a dozen of the leading petrol motors on dynamo tests. The results would be of extreme value, especially if made by an independent authority.

A PETROL BOAT

The boat shown in Fig. 138 as an example is of French origin, by F. Piramilli of Bourdeaux. She is 40 feet long, 6 feet 6 inches beam, displacement 4 tons.

DE LAHAYE MARINE MOTOR

In Fig. 139 is shown a French petrol motor with the reversing friction clutch by De Lahaye of Paris. The clutch is of ordinary make, with epicyclic gear and leather-faced friction clutches, the fly-wheel forming one-half of the one clutch.

The engine is of usual petrol type, 4-cylinder 4-cycle. It will be observed that the crank case is split in a horizontal plane and hinged, so that by unscrewing a bolt the whole top hamper can be laid over and the gearing examined. So far as it goes, this is an improvement, but it does not go far enough. Marine engines should be built with open cranks. The closed crank case, a necessity on motor cars to exclude dust and prevent leakage, is totally unnecessary on boats. The working parts of a marine engine must not only be always readily accessible, but also be visible all the time, the crank case is to be avoided.

PRIME MOVERS FOR FLYING MACHINES

Such a prime mover has been designed and described by Mr. H. E. Von Holtorp. He holds the view that durability is of little importance if the engine gives satisfaction otherwise as long as it lasts. This is true of engines employed for propelling only, that is, where the machine is of balloon type, self-supporting. But in the case of the aeroplane type, in which the machine would fall to the ground if the engine stopped, both durability and reliability would be of first importance.

The subject at present hardly comes within the sphere of practical engineering, but as it will develop it may be of interest to discuss the proposal.

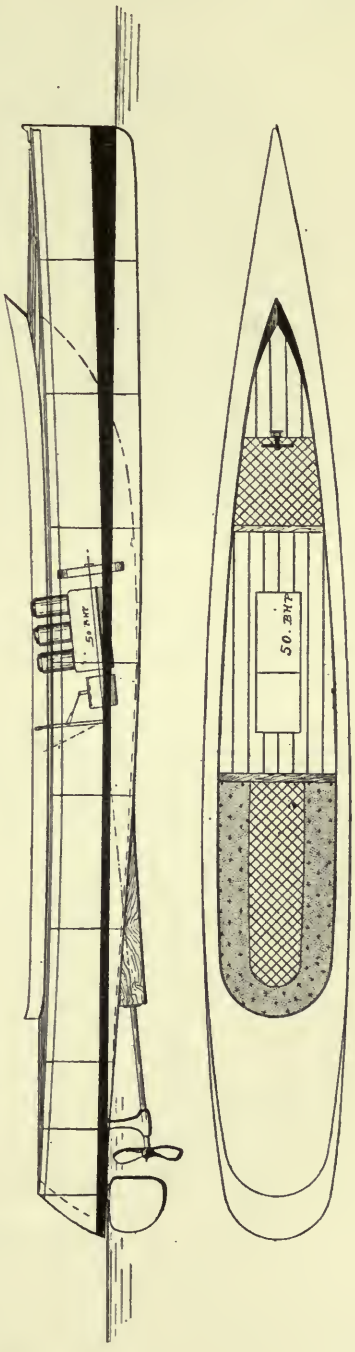


Fig. 138.—50 Brake Horse-Power Petrol Launch.

Considering the low density of air, it is certain that air propellers must be made to run at very high speeds of revolutions, or be made large in diameter. The great aim

is to obtain a prime mover, with the utmost power per lb. weight, and to obtain this it is almost certain that aeronauts must await the advent of the internal combustion turbine.

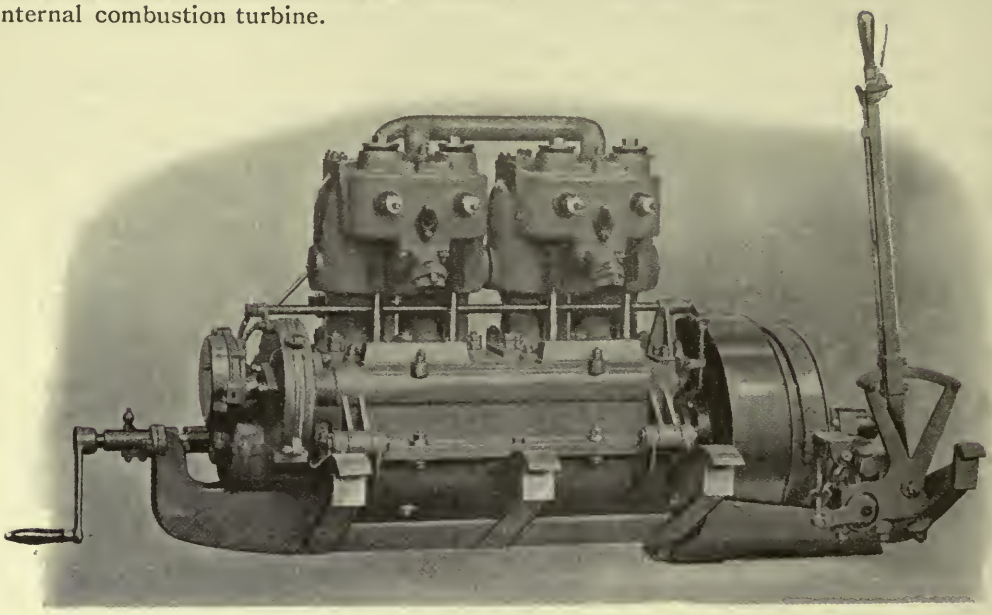


FIG. 139—Four-Cylinder Marine Motor.

The engine described and shown in the diagramatic section (Fig. 140) weighs 5 lbs. per horse-power, at 4000 revolutions per minute.

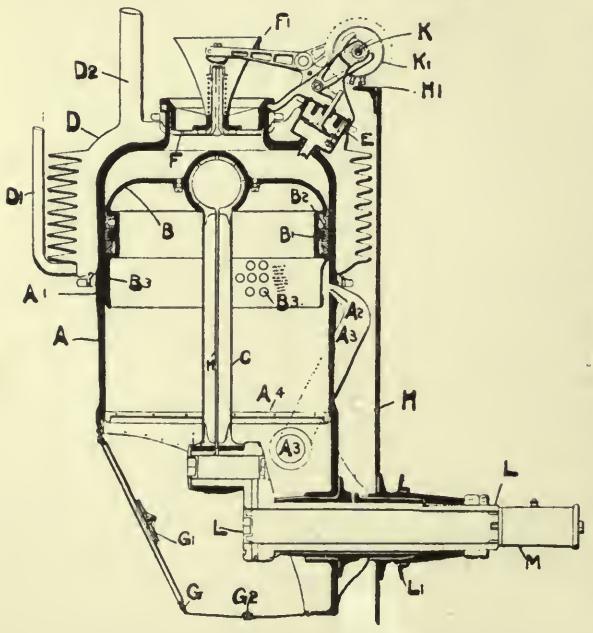


FIG. 140.—Engine for Flying Machine.

This engine is intended to work with a positive injection of petrol from the lower side of the small diaphragm pump E, which takes its supply from the tank through a ball valve. Only one valve F is used for the inlet and exhaust, and this is situated directly in the centre of the cylinder head, and is mechanically operated.

On the suction stroke this valve F is opened, and admits pure air, which is compressed on the succeeding return stroke of the piston. At the right instant the pump F is caused to inject the required petrol, and the mixture is then fired in the usual way, although it is hoped to secure spontaneous combustion—as on the Diesel engine—after suitable experiments have been carried out.

At the end of the working stroke the piston uncovers a row of ports A_1 which are drilled in the cylinder walls, and some of the exhaust gases escape to the atmosphere through them. The uncovering of similar holes A_2 on the other side of the cylinder admits a scavenging

jet of cold air, which has been previously compressed for this purpose in the crank chamber, and passes to the cylinder through the pipe A_3. The returning up-stroke of the piston clears out the exhaust into the atmosphere through the valve F, which remains open until the end of the succeeding suction stroke, when it is allowed to close. A baffle F_1 is fitted round the valve stem in order to protect it from the heat of the exhaust gases.

The inlet to the crank chamber is through the clack valve G_1, which opens inwards during the up-strokes of the piston.

The fly-wheel H is formed of a thin steel disc, which is securely fixed to the crank shaft L. The crank shaft itself has a single bearing provided in the steel wall of the crank chamber, the crank being of the overhung type. On the flanged rim of the fly-wheel is formed a multi-threaded worm, which engages with a small wheel K_1 on the cam shaft K, the gear ratio being 2 to 1 as usual. On the cam shaft are three cams, one operating the valve F, another the pump E, and the third forming a contact cam for the ignition.

CHAPTER VI

SOME RECENT TURBINES

OVENELL'S INTERNAL COMBUSTION TURBINE

This example of a first approximation of an internal combustion turbine has just been introduced, and particulars of its construction are not quite clear. But from the illustrations here shown in Fig. 141, and the details given below, we can gather that it is a turbine working on the same principles as those described on page 105 and illustrated in Fig. 109, Volume II.; also referred to in Volume I. page 191, Fig. 228.

Hitherto the great difficulty in connection with internal combustion turbines has

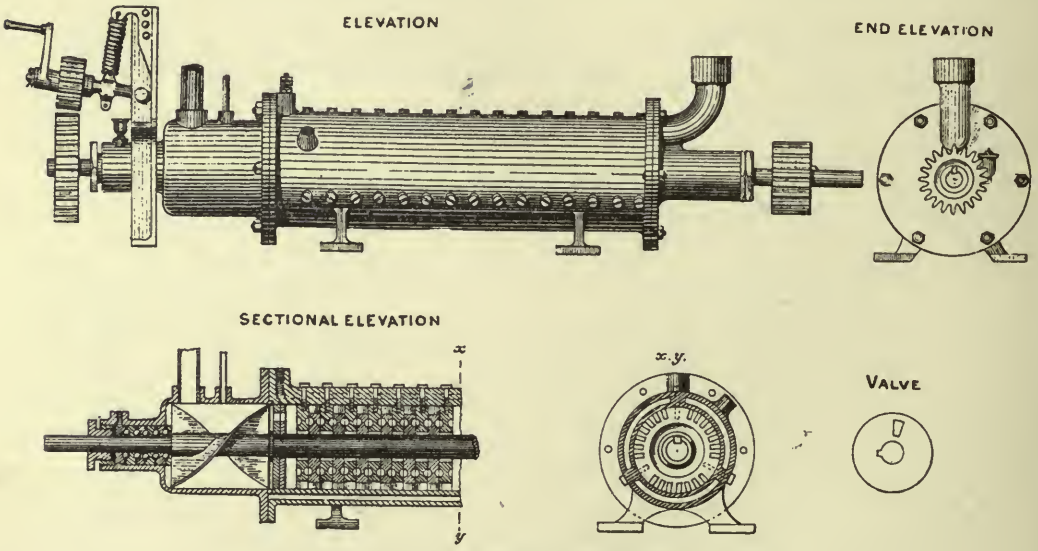


FIG. 141.—Ovenell's Internal Combustion Turbine.

been to attain the necessary compression. This inventor states that he has succeeded in overcoming this difficulty. Briefly, the motor consists of a water-jacketed cylinder, which is fitted with end covers forming the main bearings for the motor. The left-hand end cover carries a compression chamber, in which revolves a multiple-threaded screw of large area. The mixture from the carburetter, entering the chamber by the inlet, is forced forward by the action of the screw, towards a fixed valve plate having a radial port corresponding to a similar port in a revolving valve disc keyed upon the shaft and immediately behind it, the mixture being then fired by means of the

sparking plug shown; the working fluid passes along the cylinder towards the exhaust port. The valve is shown in detail in the right-hand corner of the drawing. It will be seen that the gases are deflected by the vanes, so as to strike with a maximum of effect; on leaving one disc they are again deflected on to the next, and so on to the exhaust. Both rotor and stator discs are cut out from the solid, a special milling tool having been devised for the purpose; the rotor discs are fixed to the shaft by a longitudinal feather, while the stator discs are attached to the casing each by three set screws at equal divide, and the right-hand end cover carries the exhaust outlet and a frictionless thrust block. At this end are also the regulating and timing gears. A free-wheel device is used for starting the engine, and is kept out of gear by means of a spring when the engine is running. The entry of the mixture through the valve ports when they coincide is rapid; ignition occurs directly upon the closure, the effect being that of a rapid firing magazine gun.

From this description and the illustrations it appears to be an intermittent explosion turbine. The screw pump at the entrance is designed to draw in the explosive mixture, air and petrol, and propel it forward, so that when the port in the rotating disc comes opposite the port on the fixed disc the mixture is blown into the turbine casing. So long as it is rushing in it is not ignited, as the gas flows past the ignition opening without entering it, but immediately the valve closes the gas enters the ignition, and the whole of it is then fired and, expanding, drives the turbine.

The design seems capable of considerable improvement, speaking from experience. It is not practicable to work for long with a turbine in which the combustion occurs in the wheels, or even close to the first wheel. The author in stating this may also add that the De Laval nozzle is necessary in order to expand the hot gases and so cool them, by doing useful work, before they strike the wheel blades. A fatal mistake in all internal combustion turbines which have come to the notice of the author has been that of treating them as steam turbines. Steam and permanent gas are totally different in expansion working.

The products of internal combustion can with advantage be expanded beyond that possible with steam at one step. Hence the blades of wheels for gas turbines should be much larger in area than in a steam turbine.

Beginning with a high pressure hot gas jet of small volume, it should be gradually expanded to a large volume of cooler gas at high velocity thrown against large turbine vanes. We are still a long way from a commercial form of turbine. Success will be achieved only by a very large expenditure of capital, time, and inventive ability, and a considerable amount of all three factors is at present devoted to the problems connected with this very important subject.

PARSON'S REVERSIBLE TURBINE

No turbine with curved blades of ordinary form can be reversed by interchanging its inlet and outlet connections so that the steam traverses the machine in reverse direction. Mr. Parsons introduced a double curved blade for reversing purposes, but the efficiency is low and the blades heavy, and occupy a good deal of space. They are shown in Fig. 142 in a diagram. A, A are the fixed blades, and B, B the wheel blades, both blades being shaped alike. Mr. Parsons, however, prefers the arrangement of a small reversing turbine telescoped into the larger driving turbine for marine purposes.

Quite recently another reversing turbine has been introduced, acting on a well-known principle. If the guide blades are made flat and parallel to the shaft, and the wheel blades are inclined at an angle of 45° to the axis, the effect will be the same whichever way the steam flows so far as efficiency, or rather inefficiency, is concerned; only, it

will run in either direction according to the direction of flow right or left. No other form of turbine blades has been brought out in which the turning effect is equal whichever end is inlet and outlet. It is shown in diagram in Fig. 143, and is of some interest, but of small practical value; for this form of blades, and the angles at which they are set, are the worst possible for efficiency.

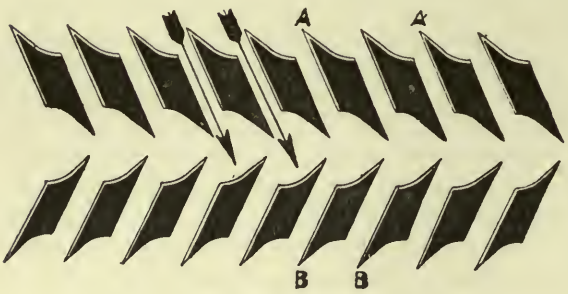


FIG. 142.—Parson's Reversible Turbine.

In all turbines the blades must be curved so that the fluid glides easily along without shock and turbulence, and the angles at which the fluid enters and leaves the wheels and guides must be determined with regard to the velocities of the fluid and the wheel blades. This is represented in Fig. 144, a diagram of two fixed rows of blades in black lines and one row of moving blades in double lines between. It will be observed that the shape of the blades is the same, fixed and movable, and the angles are nearly the same in both cases; in fact, in practice angles α and β are made equal, and angles θ and ϕ equal.

The line V represents the direction and velocity of the steam as it leaves the guide blades and strikes the wheel blades, and α is the angle of direction in which the steam is guided. θ is the angle of the face of the wheel blades to the line X,Y. β is the angle of face of the blade at the exit, and ϕ the angle of the inlet face of the guide blades to the line X,Y.

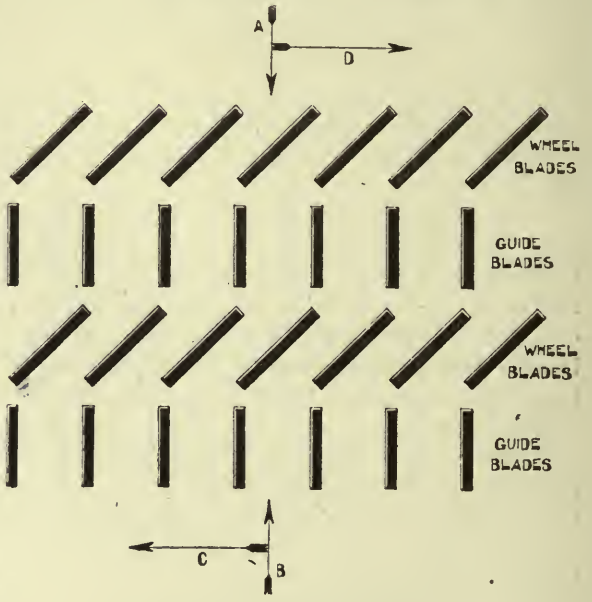


FIG. 143.—Reversible Turbine.

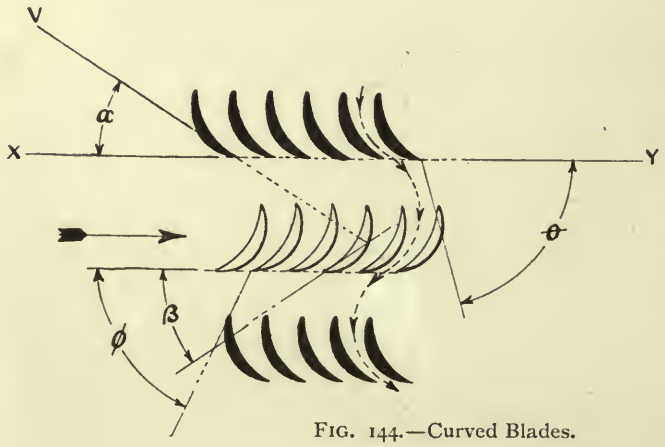


FIG. 144.—Curved Blades.

It has been shown already that the speed of the wheel must be a large fraction of the speed of the fluid—generally more than half to get fair efficiency. Two curves (Figs. 145 and 146) are here given showing the efficiency, first, when the velocity of the wheel blades is one-fourth of that of the fluid; and secondly, when the velocity is one-half and with the angle β with values between 15° and 90°,—from which it will be

seen that at the quarter speed the highest efficiency is about 72 per cent. with an angle $\beta = 15°$, and at half speed and angle $\alpha = 15°$ the efficiency is 98 per cent., so that it is evident that we could not much improve upon $\frac{V}{2} = V_2$, wherein V is velocity of fluid and V_2 velocity of wheel blades. The great loss in efficiency, however, is in practice due to escape of fluid through the clearance spaces, and by far the greatest losses are due in gas turbines to the necessity for cooling the turbine to keep it in working order.

The two types of wheels shown for reversible turbines in Figs. 142 and 143 are the only ones now proposed, and neither of them conform to the requirements for efficient working.

In the Parsons turbines the diameter of the wheels is somewhat limited by the fact that it is a parallel flow turbine, the fluid flowing through all the buckets around the

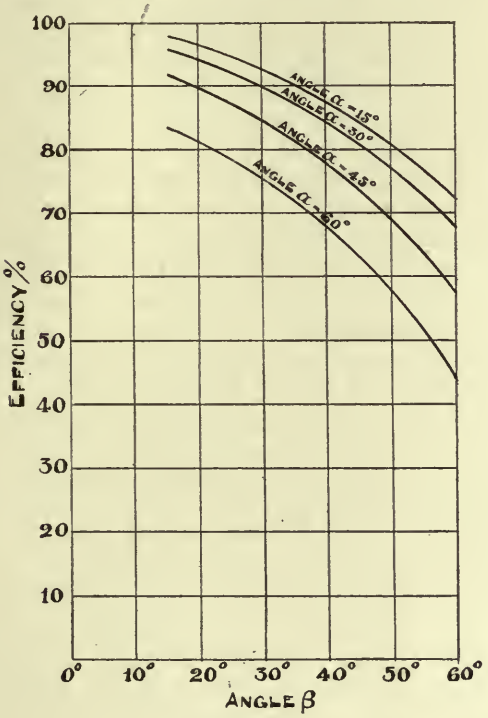


FIG. 145.

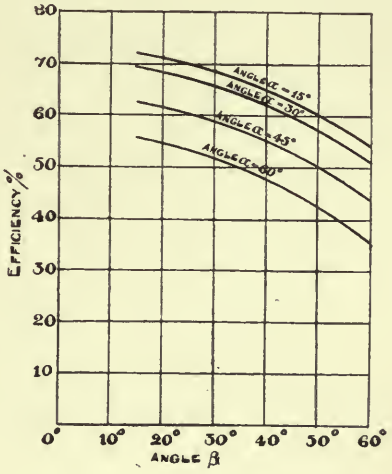


FIG. 146.

Efficiency Curves of Blades.

periphery. If, therefore, the wheels were made very large in diameter the blades would require to be very short radially, and this leads to very great leakage of fluid ; for the clearance spaces bear a larger proportion to the blade areas, the shorter the blades are made and the greater the diameter of wheel.

On the other hand, a partial flow impulse turbine has practically no leakage, and the diameter of the wheel is not limited to the same extent. De Laval, for the reasons that slow speed of revolution and large diameter of wheel makes the turbine bulky and heavy, and also because the stresses in a wheel increase more rapidly with the diameter than with the number of revolutions, chose to make his wheels small in diameter, running at high speeds. But the resources of modern engineering, in the shape of material of uniform texture and high tensile strength, coupled with machine tools of great precision and power, has rendered it possible in recent times to construct partial flow wheels working at a moderate number of turns per second, and yet with great wheel blade velocity, by making the diameter large.

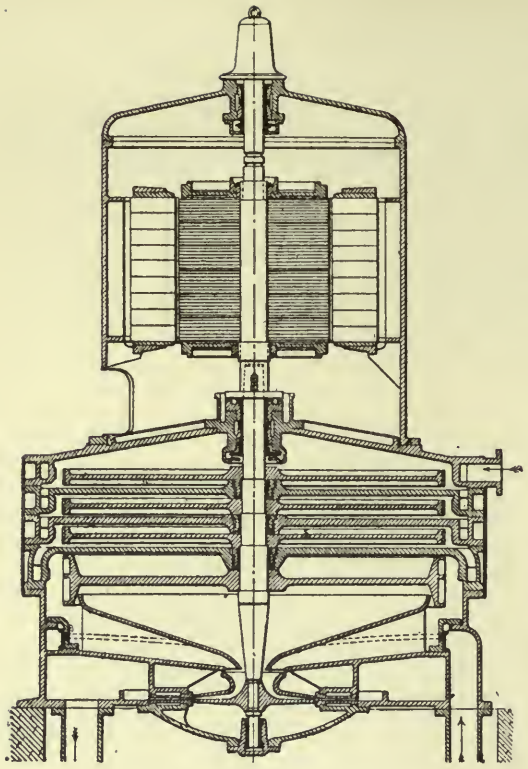


FIG. 147.—Reidler Turbine.

The Reidler stamp of turbine has been made for steam on these lines, and as it is upon the same principle modified for the purpose that the internal combustion turbine is more likely to succeed, it is worthy of consideration.

As to material, these engineers have found 10 per cent. nickel steel prove suitable. This steel was so hard, however, that it was feared strains might be set up in cutting the buckets into the circumference of the wheel; but experiments with discs, into the periphery of which slots were sawn, reassured the investigators. It will be remembered that De Laval uses thin elastic shafts. This did not seem advisable for rotors several metres in diameter, intended to transmit large powers, and the bearings—or the one bearing—were therefore placed as near the rotor as possible. The centre of gravity of the rotor was, by contract, to be within 0.1 millimetre of the geometrical mass centre. This condition was fairly well fulfilled, and the centre of gravity could afterwards be made correct within 0.01 millimetre. Under these circumstances the motion of a turbine, running at 3000 revolutions per minute, is said to be imperceptible. The wheel buckets are cut out of the solid periphery of the wheel (Fig. 150), instead of being dovetailed or riveted on. The section of a vertical shaft turbine with three wheels in series and a dynamo above is shown in Fig. 147, which conveys a good idea of the general construction. Here, however, it is the wheel which is of interest. It is shown in section in Fig. 148. Pockets are drilled into the periphery as shown in axial section at Fig. 148, and in section at right angles to the shaft at Fig. 149. The nozzles are of De Laval's type, and impinge tangentially on the wheel.

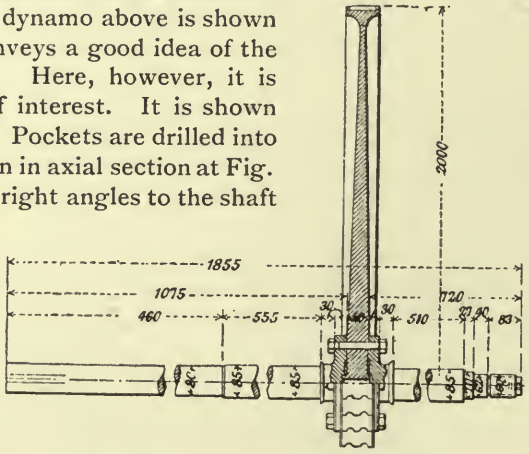
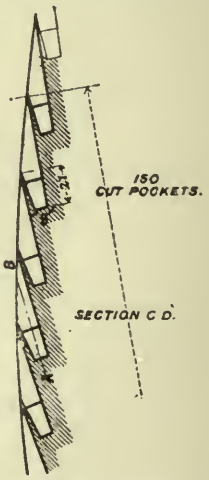


FIG. 148.—Section Reidler Wheel.



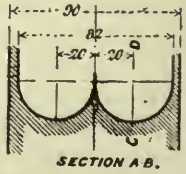


FIG. 149.—Sections of Reidler Wheel.

This turbine proves that large diameters can be used successfully if sufficient care in selecting materials and in workmanship, combined with high class tools, are provided, and this leads naturally to a great step in advance for gas turbines; for the simple reason, that a large wheel with partial flow does not suffer from high temperature fluid to the same extent as a whole flow or small wheel with partial flow,

for each blade is only subjected to the hot gases for a brief period and has time to cool in each revolution.

The cutting of the wheel buckets from the solid metal of the disc is not new, for several methods of performing this operation are shown and described in Patent 11,526 of 1894, in which it is said that the buckets of the motor wheel can be cut in the outer circumference of the body of the wheel itself, or they can be separate therefrom and retained in the wheel by an outer ring shrunk on hot, or by other means, in order to prevent them from being displaced by the centrifugal force. Fig. 151, which is a developed section, shows one way of forming the buckets a^1 in the body of the wheel a, which in this case is composed of two discs a^3, a^4, as shown in Fig. 152 and in Fig. 153, which is a sectional elevation of the wheel. The shaft or axle e can be made in one piece with one of these discs, to which the other disc is joined by a screw nut as shown, or by other convenient means. The walls a^5, a^5 between the apertures a^1, cut in the said discs near their circumferences, form wings or half buckets, and when the two discs are joined together two corresponding wings form a complete bucket with angles suitable for giving the best useful effect by the fluids, steam or gas, used for driving the turbine. In cutting the apertures a^1 a thin outside wall a^6 is left continuous around the circumference, in order to give rigidity to the wings a^5 and to avoid undue friction of the fluids, steam or gas, against the outside envelope or casing d, d of the motor.

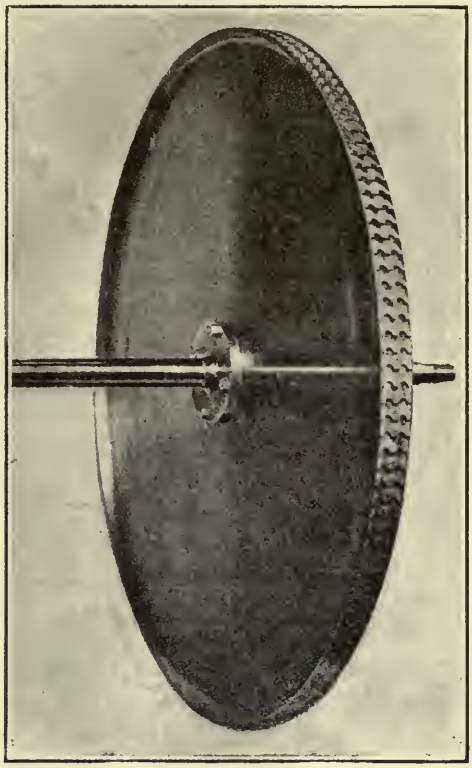


FIG. 150.—Reidler Wheel.

Figs. 154 and 155, which are sections, show a convenient way of forming the buckets in a motor wheel composed of two discs. In this arrangement radially elongated holes a^7 (Fig. 154) are first cut by a spherical ended milling cutter a^8 in the opposing surfaces of the two discs forming the wheel, a square ended milling cutter a^9 being afterwards used at an angle to form openings between the outside of the said discs and the holes a^7.

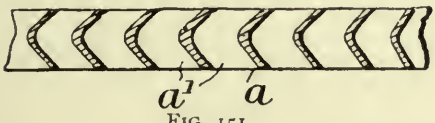


FIG. 151.

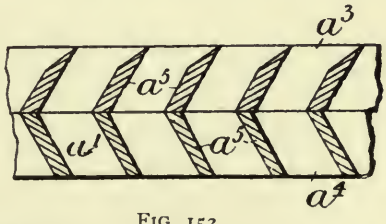


FIG. 152.

Formation of Wheel Buckets.

Figs. 156 and 157, which are sections, show another convenient way of forming the buckets in a motor wheel composed of only one disc. In this arrangement radially elongated holes a^7, a^7 are first cut on one surface of the wheel by a spherical ended milling cutter a^8 at a suitable angle, as shown in Figs. 156 and 157, and then the same

milling cutter in a second operation is caused to cut similar holes on the other surface and meeting the first mentioned holes. The apertures in both the arrangements described are finished by filing off the sharp corners. In these arrangements also a thin continuous wall a^6 is left around the circumference, in order to ensure rigidity and to prevent friction.

For internal combustion turbines it is doubtful if much advantage is to be gained by solid cast wheel blades. It is a decided advantage at high velocities to make the roots of the wheel blades the weak point in the structure of the wheels, so that in case of

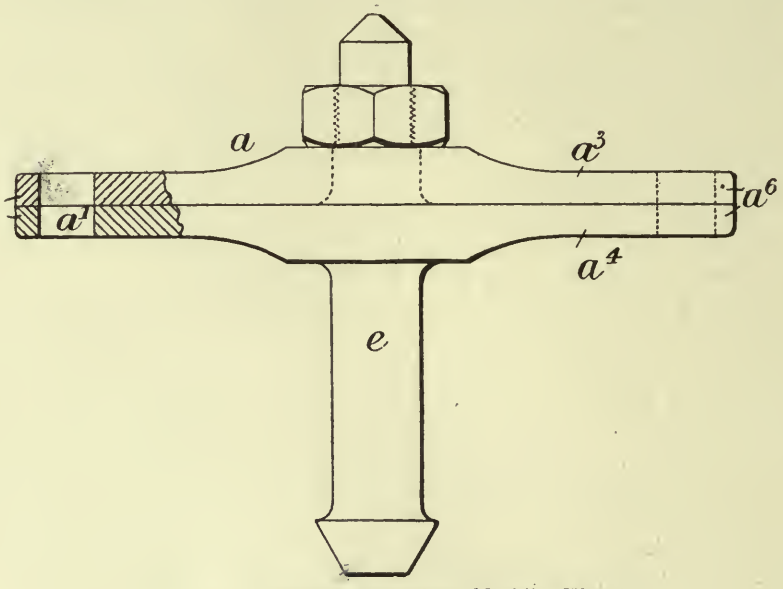


FIG. 153.—Sectional Elevation of Reidler Wheel.

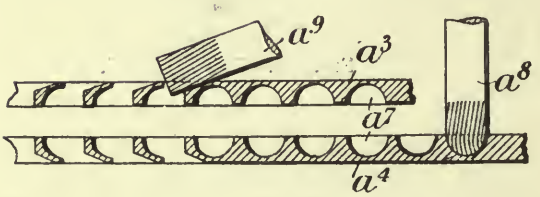


FIG. 154.

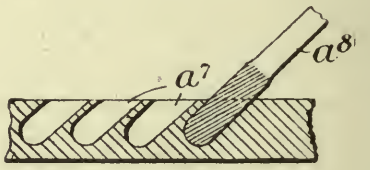


FIG. 156.

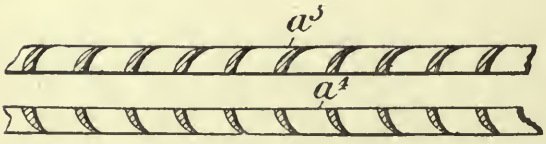


FIG. 155.

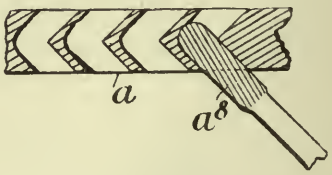


FIG. 157.

Formation of Wheel Buckets.

racing away at an abnormal speed the blades will be thrown off before any dangerous speed at which the heavy wheel might burst is reached. In the author's experience a steel wheel with copper blades, or sheet nickel blades, is preferable. If the speed should exceed a safe limit the blades are thrown off, and, being of small weight, are harmless to the casing, and the wheel, of course, soon comes to rest, as there are no blades to drive it.

THE HUSKISSON INTERNAL COMBUSTION TURBINE

In specification of British Patent No. 25,179 of 1902, particulars of this turbine are given as under with Figs. 159, 160, 161 and 162. It will be observed that the turbine belongs to the same class as that described on page 190, Volume I. of this work, and further elaborated on pages 40 and 41 of Volume II. of this work. This same inventor describes a turbine of an earlier date, No. 18,202 of 1896, described as follows with reference to Fig. 158:—

Oil from the supply pipe *h* enters holes 9 in the extension f^1 of the piston *f*, and is prevented by the rod 10 from escaping until the piston is lowered. The holes 9 then come opposite the passage j^2, and compressed air sprays the oil into the heated cylinder *j*, where it is vaporised. The air and vapour descending the coil k^1, and the compressed air descending the coil *k*, mingle, traverse the valve *m*, and are exploded in the chamber 16 by means of an electrical igniter 13. The piston *n* is forced downwards upon its fixed seat *s*, and the gases traverse the space *v* to the blades or vanes J, K, which alternate with the turbine wheels H. The air compressed within the hollow piston *n* on its descent traverses the valve 3 and the openings *o* to the chamber *r*. After the force of the explosion is spent the spring 6 reasserts itself and raises the piston. After entering at 1 and traversing the spiral M^1 can pass by the passages *t*, *v* to the turbine wheels, and the rotation of the latter by the momentum and expansion of the gases causes the archimedean screw F to force air through the centre of the turbine cylinder G. Collars a^1, a^1 in the cap *b*, *c* take the weight and thrust off the vertical turbine shaft E, which has a fly-wheel I, and imparts motion by worm gearing R, U to the mill shaft W. The power of the engine is regulated by varying the number of explosions in a given time by means of an adjustable commutator V arranged in the circuit of the electrical igniter 13.

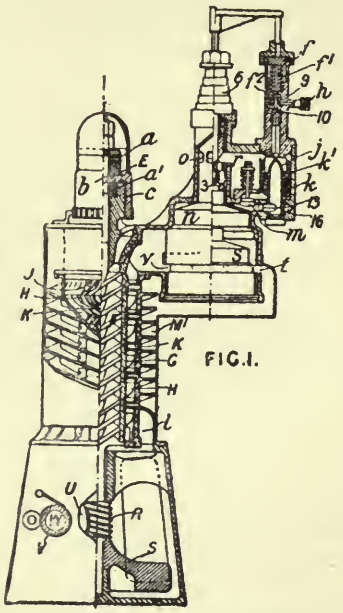


FIG. 158.—Huskisson Turbine.

The specification of 1902 is as follows, and describes fans and screw blades for air compressing, also means for producing steam from the waste heat.

This invention relates to a rotary engine of the turbine variety, the turbine wheel being impelled by the action of jets impinging on its vanes, the energy imparted to those jets being developed by the rapid combustion or explosion of oil and air, or gas and air, or any other suitable combustible or explosive mixture in a generator.

THE PRESSURE GENERATOR

The generator is a metallic egg-shaped or ellipsoidal vessel, the top of which serves as a gas dome, and the base of which is filled with a refractory material such as magnesite, dolomite, or fireclay in small lumps or in one piece with numerous perforations. This portion of the generator serves as a furnace. An outlet is provided at the top of the gas dome, which communicates with the nozzle or nozzles which direct the jets on to the turbine vanes, the passage through the nozzles being suitably tapered (the area of the cross section being greater nearer the vanes), in order to expand the jet down to atmospheric pressure before it is delivered on to the vanes of the turbine wheels.

An inlet is provided to the generator, which is arranged to direct a jet of explosive or combustible mixture into the furnace, although this jet is delivered under pressure

and at a high velocity, and immediately it strikes the refractory material composing the furnace (which has been previously heated and is afterwards kept in an incandescent state by the combustion of the jet) an explosion ensues, yet the pressure in the generator is always less than that of the incoming jet. This is arranged by making the capacity of the generator and the area of the outlet proportionately greater than the body of the incoming jet. The explosion is continuous as long as an explosive mixture issues from the inlet into the generator. In order to prevent the walls of the generator from fusing owing to the intense heat of this continuous explosion, the generator is jacketed, and water is forced under pressure in the space between the exterior of the generator and the interior of the jacket; this water is automatically kept at a predetermined level within the jacket, and steam as it is generated is allowed to escape through a pipe and nozzle into the inlet pipe to the generator, its function being twofold. First, to prevent the refractory material in the furnace from fusing and running liquid in the bottom of the furnace; secondly, in order that it may take up some of the heat due to the explosion of the mixture, and give it up to turbine wheel in the form of energy, a removable plug is fitted in the bottom of the furnace, for heating up before starting, and it is arranged that the jets after they have impinged on the vanes of the turbine

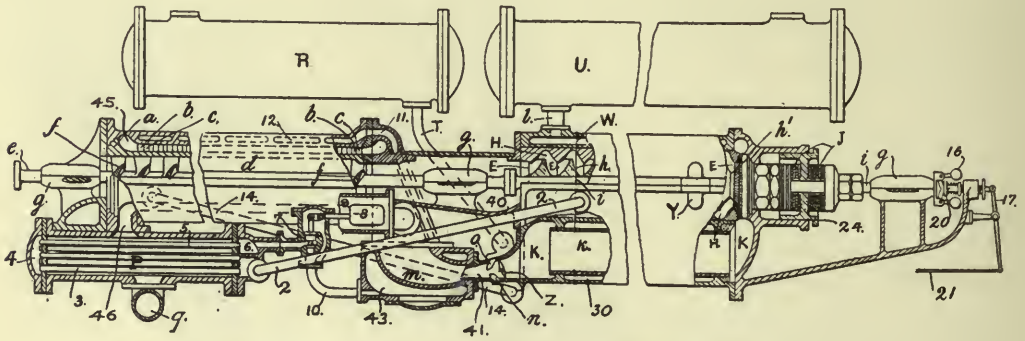


FIG. 159.—Sectional Elevation of Huskisson Turbine.

wheel shall be deflected off and strike on to the pipe conveying water to the water jacket, and so be condensed.

The improvements consist chiefly in reducing the temperature in the combustion chamber, in carrying off the heat rapidly from the parts exposed to the hot gases, in providing a condenser, and in eliminating reciprocating valves, pumps, and other devices which gave trouble in the engine described in specification of 1896, and in subsequent engines.

This invention will be readily understood on reference to Figs. 159, 160, 161, and 162, which illustrate the invention as applied to a parallel flow turbine of the multiple series type, exhausting into a condenser, and driving an outward flow compressor of the multiple series type delivering into a receiver from which the generator is supplied.

Fig. 159 illustrates a side elevation of the machine, partly in section.

Fig. 160 is a cross section through the turbine and condenser, on the right hand side disclosing a section through the exhaust passage, and on the left hand side a section through the steam escape passage from the turbine casing jacket.

Fig. 161 illustrates an end elevation of the generator, looking from the compressor toward the turbine, disclosing the air inlet passage 40 to the compressor, the inlet 41, where the combustible is admitted to the furnace; the outlet branch 11, from the generator to the turbine casing jacket 12, and the branch 9 for the automatic feed to the generator jacket 43.

Fig. 162 illustrates a cross section end elevation through the compressor, air, oil, and water reservoirs.

The turbine wheel consists of a hollow tube *a*, on the exterior of which a number of complete rings of vanes or buckets *b* are fixed. There is a short space on the tube between each ring of buckets, in which similar rings of vanes *c* are fixed; these are stationary directing vanes, and are secured to the casing *d* of the turbine. The directing vanes *c* direct the jets of gases or products of combustion on to the buckets *b* on the turbine wheel, and so cause the turbine wheel to rotate on its axis. The hollow turbine wheel *a* is mounted on the tips of a number of air propeller blades *f*, which are solid with the turbine spindle *e*; this spindle rotates in bearings *g*. The arrangement is such that when the turbine wheel *a* revolves, the blades *f* force air along the interior of the tube into the compressor; the object of taking the air through the interior of the turbine wheel is to keep the temperature down and prevent the turbine buckets *b*, which are in the wash of the hot gases, from being burnt out. The compressor consists of a number of discs of outward flow fans *h*, all threaded on the spindle *i*, which is coupled to the spindle *e*. Each of these fans takes in air at its centre E, and discharges

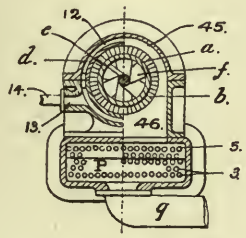


Fig. 160.—Cross Section.

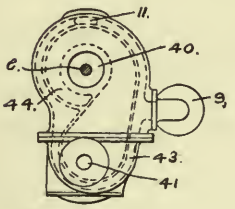


Fig. 161.—End View.

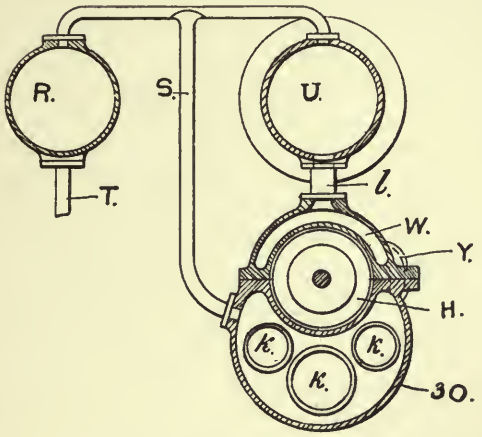


Fig. 162.—Cross Section.

Huskisson Turbine.

it at its periphery into the annular chamber H, which communicates with the centre E of the next fan, where it is picked up and discharged, and so on in a similar manner until the air has passed through all the fans of the series. The pressure of the air is raised by each fan. The last fan h^1 forms a balance piston, and the compressed air is discharged from it into the reservoir K and the three reservoir tubes *k*, *k*, *k*, from thence it escapes past the throttle valve Z into the generator *m*. The air reservoir is provided in order to supply the generator with a steady flow of air under pressure, and so avoid backflashing and spasmodic action of any description.

The generator *m* is shown in Figs. 159 and 161, and is a jacketed vessel. Combustion takes place in the base, the combustible being supplied through the inlet 41, the fuel being supplied through the valve *o*, as will be subsequently explained, while steam issues from the valve *n*, and air past the valve Z. On this combustible mixture passing into the base of the combustion chamber or generator *m*, and combustion taking place, a portion of the heat evolved is utilised in superheating the steam (which is a component of the mixture), and the pressure in the generator *m*, in spite of the great expansion of the body of the mixture due to the rapid combustion or explosion of the same,

is always less than that of the incoming jet of combustible mixture, because the capacity of the generator *m* is very much greater than that of the body of the jet issuing through the inlet 41, and the products of combustion have a free outlet at the top of the chamber, which, as is shown in Fig. 161, terminates in a passage 44, which is curved round to embrace the circumference of the first ring of directing vanes *c*.

The combustion is continuous so long as a jet of combustible issues from the inlet 41, and gases at a high velocity and pressure are delivered on to the turbine wheel *a*, directed on to it by the stationary directing vanes *c*. Gulping, backflashing, and spasmodic action is avoided by the large capacity air reservoir, and the burnt gases do not mix with and retard the combustion of the incoming jet of combustible, because the burnt gases are passing out of the outlets at the top of the generator at a high velocity, and follow an easy and direct path from the inlet, so eddying of the burnt gases is entirely prevented. On issuing from the top of the generator *m* the gases pass the first set or ring of stationary directing vanes *c*, and are directed by these on to the first set of revolving vanes or buckets *b* (on to the turbine wheel *a*); the gases react off these buckets on to the second set of directing vanes *c*, and are directed by these on to the second set of revolving buckets *b*, and react from these on to the third set of stationary vanes *c*, and are directed by these against the third set of revolving buckets *b*, and so on through all the series of stationary vanes *c* and revolving buckets *b*, until the gases finally escape from the last set of revolving buckets *b* into the annular exhaust chamber 45 formed in the turbine casing.

The speed of the turbine is governed by the ball governor 16, which acts on the sliding sleeve 20, and actuates the lever 17 and the transmission rod 21, which is attached to bell crank levers working the valves *n*, *o*, Z, controlling the amount of steam, oil, and air passing through them respectively—the amount passing through these valves always bearing a constant ratio, so that the mixture of the combustible is kept constant, as the pressure in the water tank U and oil tank R and air reservoir K is always kept equal by the equalising pipes S.

It will be evident that any suitable media can be used in the combustion chamber instead of steam, to lower the temperature in that vessel. Such a medium should be capable of rapidly absorbing heat and of rapidly expanding under the action of heat.

An exhauster pump or fan can be fitted to the exhaust pipe *g* for creating a vacuum in the condenser.

This turbine is a constant pressure machine, the principles of which were foreshadowed by Parsons in his 1884 patent. The details are pretty well thought out in this later patent of Huskisson's, but it seems somewhat complicated. The inventor speaks of continuous "explosions" without intermission, but in the ordinary use of the word "explosion" the word conveys the idea of intermission, a sudden expansion with great force for a brief period of time. As a matter of fact, according to the specification there would be no explosions at all, but a continuous combustion at high pressure.

The means for working the air through the interior of the turbine for cooling purposes, the condenser, and the fan compressors are interesting, and may overcome some of the difficulties; but all these things absorb power and become sources of trouble in practice, so that it requires nothing less than actual proof in running turbines to show that they save as much as they waste.

Again, there is a difference between steam turbines and gas turbines. Steam is used as a continuous current of fluid, but gas seems to require intermittent flow, a succession of blasts short and powerful so as to obtain as much impulse as possible in a short time, in order to get as much work done as possible before heat is conducted away. The turbine question has been here again introduced, as the information regarding these new ones has just come to hand. In all probability a successful turbine with gas, oil, and petrol will be on the market within the next twelve months.

RECENT DEVELOPMENTS IN OECHELHAEUSER ENGINES

The Oechelhaeuser engine has been improved in several ways, and so also have the other engines designed for large powers from furnace and producer gases; hence before closing this work on Internal Combustion Engines, these recent developments are introduced.

Fig. 163 represents Oechelhaeuser's most recent improvements in combining two engines on one shaft.

In twin engines with two pistons reciprocating oppositely within each cylinder the object of the invention is mainly to reduce the number of cranks and bearings employed, and to improve the disposition of the bearings. Fig. 163 shows one of the arrangements in plan. In this the two front pistons work on a crank shaft *b* directly, and the two rear pistons work on a central crank on the same shaft through the medium of a rocking shaft *l* and return connecting rods *h*. In another arrangement a reciprocating cross head is substituted for the rocking shaft *l*; and in a third arrangement the connecting rod *h* is outside instead of between the two cylinders. In modifications, instead of a rocking shaft, rotary shafts may be employed at the rear ends of the cylinders, and in that case the two cylinders may be disposed in line on opposite sides of a central crank shaft. The air compressor or the mixing pump for the motor may be operated from the rocking shaft.

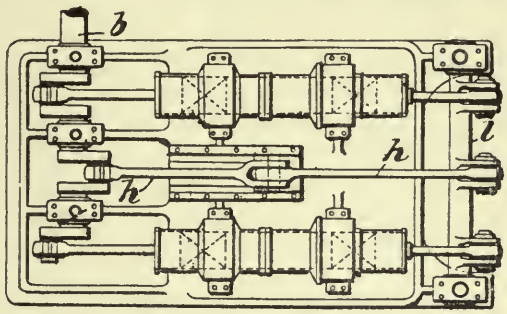


Fig. 163.—Oechelhaeuser's Engine.

There are at present some other engines being brought out of very considerable interest, some details of which have been given us, but owing to patent rights full details and illustrations are withheld for a time; but in a future volume these will form a chapter of great value, as they embody the most modern practice and theory.

PRACTICAL CONSIDERATIONS ON GAS ENGINES

The great questions of preignition, mean pressures, initial pressures, and other important topics are worth considering fully. They have been exhaustively treated in Mr. D. Clerk's classical paper in the James Forrest lecture at the Institution of Civil Engineers, 1904, from which the following views expounded are quoted:—

This question of preignitions limits the engine designer in many ways, and it becomes absolutely necessary to preserve the inflammable mixture during compression at a temperature below its igniting-point. Any inflammable mixture only requires to be sufficiently compressed to ignite without any other means of inflammation. Unfortunately, the conditions of maximum economy in engines are also conditions which favour preignition.

In small engines preignitions are rare and are not dangerous; in large engines they are, unfortunately, somewhat frequent, unless mean pressures be kept down and extensive cooling adopted; and when they do occur, they are somewhat dangerous.

It is unfortunate also that no exact knowledge exists as to the temperature of ignition of different gaseous mixtures, and the engineer has been obliged to accumulate very considerable knowledge of the subject by the simple process of pushing his compression with each gaseous fuel as high as he dare without producing preignition. If with any fuel he produces preignitions, then he at once alters his compression space and other parts so as to reduce the compression.

It is found, for example, that with weak gases of the producer type, such as blast-

furnace gas, compressions may be carried very much further than with very inflammable gases, such as town gas or natural gas. As a rule, it may be taken that gases which are rich in hydrogen are highly inflammable, and preignite readily. Such dangerous mixtures can only be compressed to a moderate degree without risk. It has been found, for example, that in petrol engines the compression can be carried higher than in heavy oil engines, and that with some kinds of heavy oil compression must be lower than with other kinds. On the other hand, it appears that with alcohol as the fuel compressions can be carried very much higher than with petrol.

At present the engineer knows, from previous experience, that if he carries his compression beyond a certain limit for a certain gas he will at once make his engine relatively unworkable by frequent preignitions. The great limiting element in all internal combustion motors, so far as high compressions are concerned, is this one of preignition. Preignitions are due to many causes—sometimes to a small incandescent part of metal within the cylinder; sometimes to a porous surface of metal within the cylinder; sometimes to a hot piston end; sometimes to an overheated exhaust valve; and possibly to charred matter of carbon deposited in the cylinder. In all cases, however, preignition occurs owing to the tendency of these engines to be overheated. In large engines, of perhaps 200 horse-power and upwards, preignitions are only avoided by excessive water cooling of all parts, and a plentiful flow of cooling water at low temperature.

Definite chemical information is much wanted on the ignition-points of various gaseous mixtures when treated under internal combustion motor conditions in fairly large volumes. Experiments, such as chemists sometimes conduct, in narrow glass or metal tubes, are of little use in considering this question of preignition. Such experiments, if made, would require to be performed with comparatively large bodies of material exposed for definite fractions of a second to certain graduated temperatures.

It has been found that in large engines the reduction of cooling surface can be carried too far. In small motors the better the surface arrangements the better for the economy of the engine; but in large engines the practical point is the more important point, so that cooling surfaces are deliberately increased in proportions for the purpose of reducing this difficulty.

It is obviously better to have a safe smoothly running engine which does not give the best theoretical diagram than to have an engine producing beautiful thermal results that is always on the verge of danger. While on this point, it must never be forgotten that the engineer frequently deliberately abandons the path of theoretical rectitude in order to obtain success in the practical operation of his mechanism. It by no means follows that he is ignorant of this path, as is too often assumed by some of our more theoretical friends.

It will be seen that the temperature at which preignition occurs depends on the nature of the gas used; and so the engineer may regulate his compression, rate of cooling, and other circumstances to keep his mixture lower than this point. From this it will be seen that one of the great limitations imposed on the large engine is due to excessive heat flow through the enclosing walls. It is well known to engineers that this heat flow increases with increase of explosion temperature. Notwithstanding this, in the smaller engines the tendency of recent years has been to increase flame temperatures within the cylinders to the highest safe economical point, because each maker desires to sell an engine giving the greatest power as well as economy for a given price. The problem is, in the end, a commercial one; and the pressure of competition in the end forces the designer to get not only the highest economy, but also the highest safe power limit for compressions and dimensions of the engine.

This question of high mean pressures is a most important one. In many of the large gas engines the mean working pressures are relatively low—in the large Continental engines mostly 60 lbs. per square inch or under. British built engines

usually operate the medium sizes at pressures as high as 90 lbs. and 100 lbs. per square inch, and the English engineer at present is by no means satisfied with the average pressures which he can safely employ in existing large gas engines. To obtain high mean pressures is to have an engine of great power for small dimensions ; but if flame temperatures be reduced to prevent heat-flow difficulties, and save heat in this way, the mean pressure is also reduced. It is very desirable to reduce heat flow, especially in large gas engines.

Mr. D. Clerk describes a very important improvement made by himself, and applicable to almost all internal combustion engines ; it is best put in his own words :—

"Some time ago it appeared possible to reduce maximum temperatures while increasing mean pressures by increasing the charge weight per stroke given to an engine. He had experimented with two engines, one of 7-inch cylinder by 15-inch stroke, and another of 10-inch cylinder by 18 inch stroke. These engines, which are of the standard 4-cycle type, are allowed to take in the usual charge of gas and air, then, at the end of the stroke a further charge of air or other inert fluid is added to increase the pressure in the cylinder to 7 lbs. or 8 lbs. per square inch above atmosphere before the return of the piston begins. This has the effect of increasing the charge

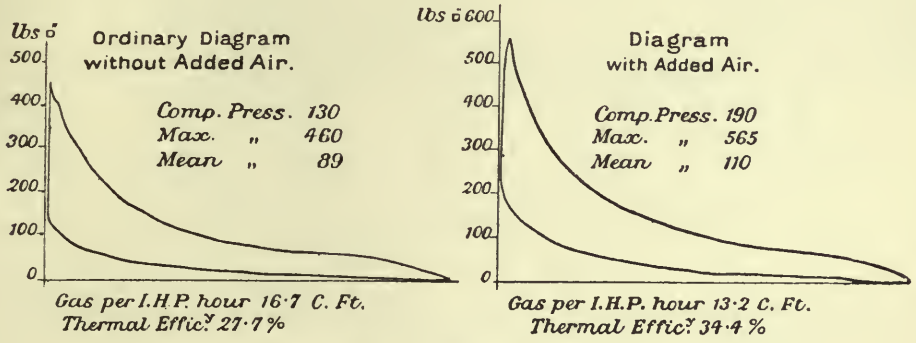


Fig. 164.—Average Diagrams from 10-inch × 18-inch National Engine.

weight present in the cylinder by about 40 per cent., and of increasing the pressure of compression without, however, increasing the temperature of compression. Indeed, in both experiments the temperature of compression was diminished. As the charge present is constant so far as gas is concerned, the maximum temperature capable of being produced is much reduced. The maximum temperature in the diagrams taken by him from these two engines is about 1200° C. Experiments were made, and it was found that the heat flow was reduced to about two-thirds ; and further, that the mean available pressure was increased about 20 per cent.

"Fig. 164 shows two indicator diagrams from the 10-inch by 18-inch engine. One diagram is from the engine in its ordinary state ; the other diagram shows the effect of adding air. In both cases the gas present per charge is practically the same. It will be observed that 20 per cent. more power is obtained with a proportionately reduced consumption of gas. The figures obtained have been marked upon the diagrams.

"This method supplies another means of increasing the economy of these engines without changing the thermodynamic efficiency, simply by reducing heat losses ; that is, in these cases the economy is effected with a heat cycle of unchanged thermodynamic efficiency by effecting a change in the heat flow through the cylinder walls. This method of increasing practical efficiency has the merit of reducing temperatures all round, and preventing preignitions in two directions, namely, by temperature reduction

and also by reducing the average inflammability of the charge, so that it is less readily ignited on compression."

The large "National" gas engine shown at Fig. 165 is designed to work with high mean pressures and low flame temperatures. The front end of the cylinder is used to compress air into a space; this air is passed through ports to the charge which has been sucked in on the other side, and the charge weight is thus increased without adding more inflammable material. When compression takes place the pressure rises to about 200 lbs. per square inch; then, on ignition, pressure is obtained equal to about 500 lbs. per square inch. This engine has been designed for mean available pressures of about 130 lbs. per square inch, and maximum flame temperatures of about 1200°. I cannot but think that it is desirable in large engines to keep cylinder dimensions as small as possible, in order to minimise expansion difficulties and to raise the maximum

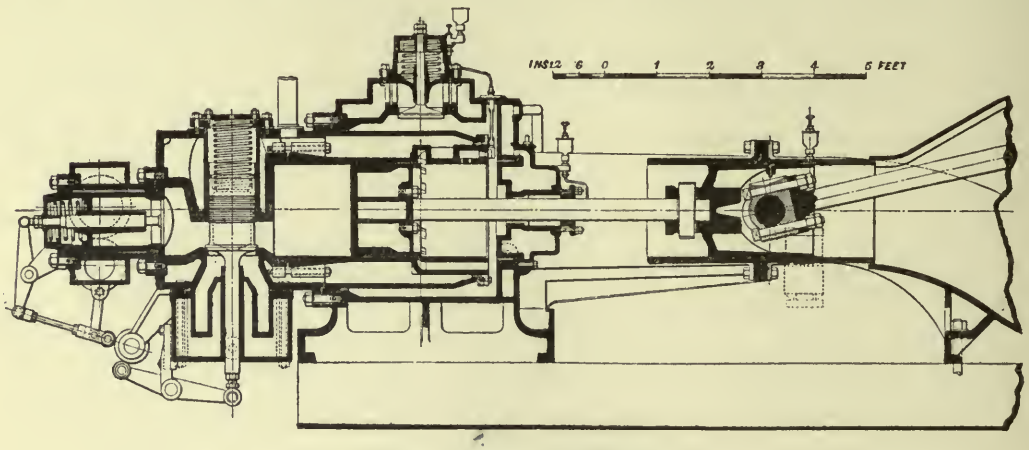


Fig. 165.—National Gas Engine.

working pressures to limits far above those at present used. This method of reducing temperatures appears to be worthy of great attention.

The conclusions come to by Mr. D. Clerk are similar to those previously expressed in regard to the internal combustion engine and its future, and are as follow:—

England stands at the head of all nations in the production of the smaller and medium sized fixed gas engines. She has produced altogether something approaching 100,000 engines of an average of 20 horse-power. This is greatly in excess of the whole Continental output of engines of this type taken together. On the other hand, Continental engineers have given more attention to the large gas engine—engines of 500 horse-power and above, and the application of blast-furnace gas to the use of the large engine. In this field of internal combustion motor work Germany excels.

In the petrol motors for motor carriages France appears to take the lead, and in heavy oil engines England takes the lead. In America engineers are now giving considerable attention to the internal combustion motor, and have taken considerable part in the application of petrol motors to small vessels and boats.

It may be said, without exaggeration, that the whole world is now alive to the possibilities of the internal combustion motor, and that progress will be more and more rapid. These motors have almost fulfilled the expectations of those engineers who have devoted a large part of their lives to their study and advancement. They are looking forward now to the completion of the work begun so many years ago, and expect at no distant date to find the internal combustion motor competing with the steam engine even in its latest form—the steam turbine—on sea as vigorously as it does at present on land.

"England" is referred to in the above comparison instead of "Great Britain," because Scotland has hitherto strangely neglected the gas and oil engine industry. Although some efforts were made some twenty years ago to establish the manufacture in Glasgow, but little progress was made. At the present time there are two or three makers of petrol autocar engines, to which we have already referred. Manchester is the centre of gravity round which the gas engine world revolved for years (the same may be said of electrical engineering), but there is an awakening in engineering circles to the fact that another era has begun. Steam was the prime mover of the last century; gas and internal combustion engines are to be the prime movers of the present century. That is beyond all doubt.

Internal combustion prime movers, and the electrical transmission and distribution of their power, are the two leading lines of progress in the world's future engineering, and the prime mover is of far more importance than the transmitter or distributor, for

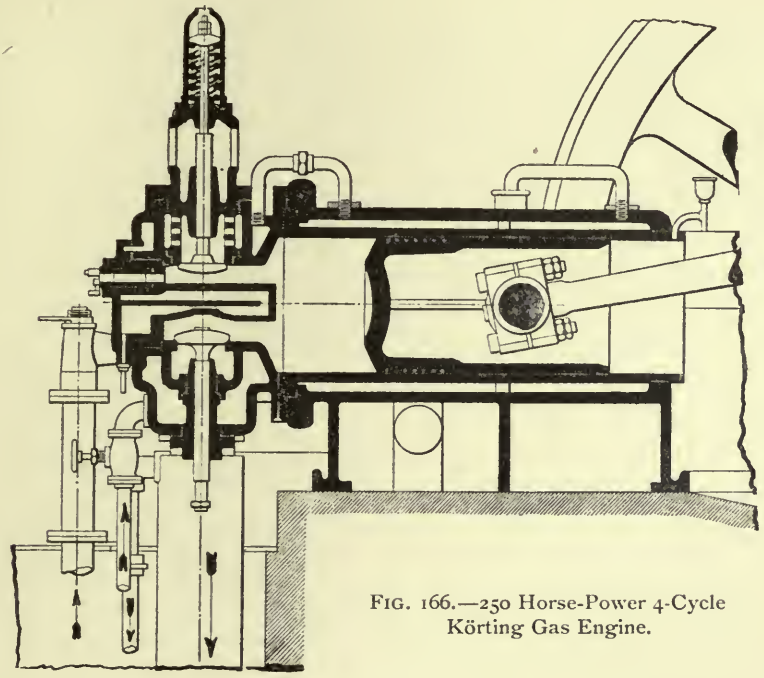


FIG. 166.—250 Horse-Power 4-Cycle Körting Gas Engine.

in many instances the prime mover can do its work without electricity at all. While no electrical work of any kind can be done without the prime mover, excepting the little that can be done by galvanic batteries, the prime mover is the prime factor in all commercial electrical supplies of energy.

Fig. 166 is a section of a 250 horse-power Körting 4-cycle engine, in which the difficulty of overheated combustion space and exhaust products is very frankly met. Here a projecting tube has been deliberately inserted into the combustion space provided with a water circulation to increase the rate of cooling. Such devices are bad from the point of view of heat economy, but they enable these large engines to operate successfully without preignition.

A vertical Oechelhaeuser type of engine, with two open-ended pistons in one plain cylinder, seems to be the form most likely to work at a low temperature; a thin tubular liner in the cylinder, well water-jacketed, takes up an enormous quantity of heat, and the improvement of Mr. D. Clerk's can be applied by adding air to the charge to increase the pressure on compression.

DIFFERENCE BETWEEN STEAM AND GAS POWER

The designing of a reversible internal combustion engine as easily reversed as a steam engine is not beyond the possibilities of the future. But still, after that problem is solved there will be the fundamental difference in action. In the steam engine the fluid can maintain a steady powerful static pressure for any length of time, without much waste of steam. If the piston does not move the steam does not escape, but still the pressure on the piston is maintained. That is not so in internal combustion engines; in all these hitherto devised the pressure is only temporary, and if the piston does not move, the pressure falls rapidly. It is only an instantaneous pressure. Hence if we desire to obtain a strong sustained effort, of a pull, or push, the engine must be started up free of load, and the load applied by a friction clutch or electric transmission when full speed has been attained. And then we must trust to the momentum of the fly-wheel and moving parts to carry the engine over the heavy pull between explosions. It is no easy matter by means of a brake to stop a steam engine with two cylinders on cranks at right angles, or three cylinders and cranks at 120. It is much easier to arrest the motion of an internal combustion engine; and while slipping on the clutch allows an engine to keep going, the power is dissipated as heat and lost. Similarly with a turbine, if the brake is applied to a turbine until it is stopped the steam still blows through, doing no work—it is all lost, and so it is with electromotors. If an electromotor is braked so as to slow it down to a stop, the current would increase as it slowed down and the fuse would blow out. But if we screw on the brake first, and then turn on the current through a rheostat and an ammeter, it will be seen that a large current can flow through the motor, while the motor does no work, standing still, it only becomes heated; with steam behind a piston, if no work is done no current of steam flows.

CHAPTER VII

STEAM AUTOCAR ENGINES

Steam still holds a prominent position on vehicles of all kinds—road, rail, and water. The perfection of the engine, its simplicity, ease of manipulation, silence, and smooth working much recommending it. The boiler is the weak part of the steam engine. We are too apt to look upon steam engines without considering the boiler, without which, however, it would be no engine; the boiler is as much an essential part of the steam engine as the cylinder or piston. Small boilers require expenditure of time, money, and care out of all proportion to their power, requiring more than a large boiler. The subject of autocar boilers will be considered more fully presently. We may at present note the type of prime movers working by steam, and begin with one built on the model of the petrol engine made by the Motor Construction Company of Nottingham. Fig. 167 is a sectional end view and sectional elevation of this engine, which develops about 30 horse-power, working with a pressure of from 400 lbs. to 500 lbs. to the square inch. When the first tests were made of the motor the pressure available was only some 200 lbs. per square inch mean, instead of the ordinary working pressure before mentioned; but on the basis of the extra power developed by the use of the increased pressure it would be safe to assume that 30 effective horse-power is obtainable. The motor consists of four trunk cylinders as shown by AA, opposed to one another in pairs at an angle shown by the cross section. The cylinders are attached to a rigidly constructed crank chamber BB, the pistons CC acting upon the crank shaft DD, the crank pins of which are set at an angle of 180°. Steam is supplied to the cylinders through the medium of ordinary mushroom pattern valves, as shown by E. These valves are operated by a cam shaft FF, located between the cylinders and above the crank chamber, movement being imparted to the overhead shaft FF through the medium of spur gear wheels GG. The cut-off of the inlet valves is variable through the longitudinal movement of the cam shaft FF, which is effected by means of an arm H connected to the cam shaft FF, through the medium of a double thrust ball bearing J. The exhaust steam is passed from the engine by means of valves placed beside the inlet valves, and similar to them in form. The reversing of the engine is also effected by the movement of the cam shaft FF.

Considerable attention has been paid to the system of lubrication of the engine, which is effected by means of an oscillating pump K contained within the engine crank chamber. The oscillating movement of the pump is employed to open and close the suction and delivery ports, the pressure on the lubricant being 30 lbs. per square inch. The pump first delivers oil to the crank shaft bearings. The crank shaft DD is provided with oil ways through its centres, and oil under pressure enters these oil ways through suitable channels in the journals of the crank shaft. Other ports in the crank pins deliver the lubricant to the big ends of the connecting rods. The oil is conveyed to the gudgeon pins in the piston by means of tubes. A paraffin burner and flash boiler

are used in this engine; the engine has two pumps, one for pumping oil fuel and the other for water for the boiler. These are driven off the cam shaft. The weight of this engine with pumps (as usual not including boiler) is 143 lbs., length 18½ inches, height 17 inches, breadth 18½ inches. To test vibration, a penny piece can be balanced on its edge while the engine is running. This is an old test. It will be found, however, that a good new penny, or one not much worn, will stand on its edge even while some vibration exists. However that may be, it is a very severe test on a motor car engine, and proves that the balance is excellent.

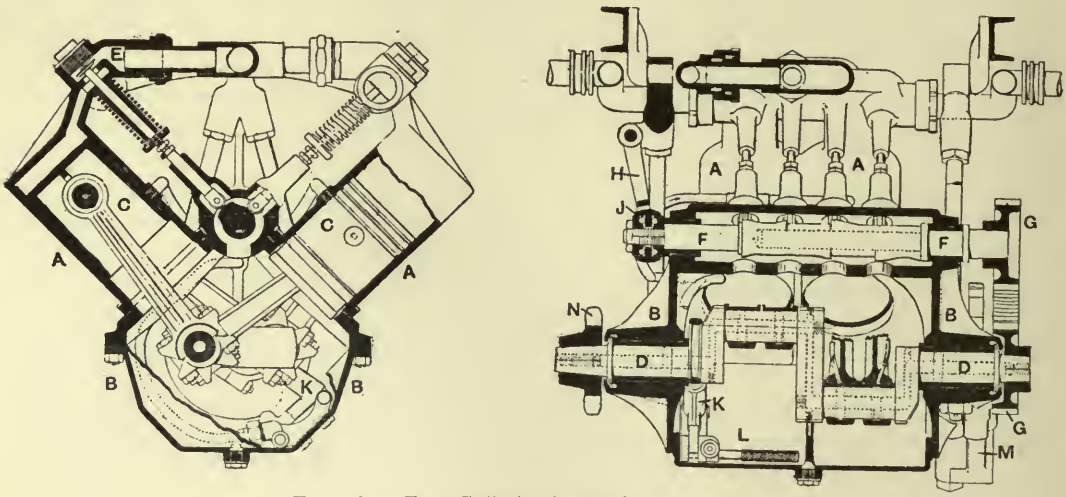


FIG. 167.—Four-Cylinder Steam Autocar Engine.

Cross section—

AA, Cylinders.
BB, Crank chamber.
CC, Pistons.
DD, Crank shaft.
E, Steam valve.
FF, Cam shaft.
GG, Gear wheels operating FF.
H, Arm giving end motion to FF.
J, Double ball thrust bearing on H.
K, Oil pump.

Longitudinal section—

L, Oil strainer attached to K.
M, Fuel and water pump.
N, Sprocket wheel on crank shaft.

THE MIESSE STEAM AUTOCAR ENGINE

This engine belongs to the type of flash boiler engines, and is a good example of its kind.

In the Miesse system the generator is built up of several layers of steel tubes, and is heated by a special form of burner which uses ordinary paraffin as a fuel. The water is forced into one end of the generator either by a hand pump when starting, or by a mechanically driven pump when the car is running; the quantity of water which is delivered by the latter pump depends upon the speed at which the car is running, but the actual amount which finds its way into the generator is regulated by hand, any surplus being allowed to find its way back to the supply tank. The hand regulator consists of a bypass, and it primarily enables the driver to regulate the steam pressure. The steam is taken direct from the other end of the generator to the engine, and the engine is controlled by varying the cut-off and reversing gear; in all cases a throttle valve is also fitted, and it is so arranged as to be closed by depressing a foot pedal. A safety valve and a hand-operated relief valve are provided on branch pipes between the water-feed pump and the generator, but the steam pipe from the generator runs direct to the engine

and has no branch connections of any kind. The heat of the burner is entirely regulated by hand, and the fuel is fed from the supply tank to it under pressure. The pressure in the tank is automatically maintained, when running by a pump driven off the crank shaft of the engine, the degree of pressure being kept constant by a relief valve which opens when the desired pressure has been attained. The oil on its way to the burner passes through a single vaporising coil which lies above the burner, and the gas generated in the vaporiser is led through the regulating valve to a single nozzle, which projects into a pipe forming part of the burner. The quantity of gas is controlled by the driver, but there is no regulator for the air. The air and gas pass along the pipe into a chamber from which a large number of parallel horizontal tubes project beneath the generator. The tubes are perforated with rows of fine holes, drilled at an angle, which form the burner jets. The burnt gases are conducted from above the generator by a flue passing across it, and down behind it; the flue is open to the air in front, and the necessary draught is created by the forward travel of the car. The engine is lubricated entirely on the splash system, oil being fed into the crank chamber for this purpose. The engine

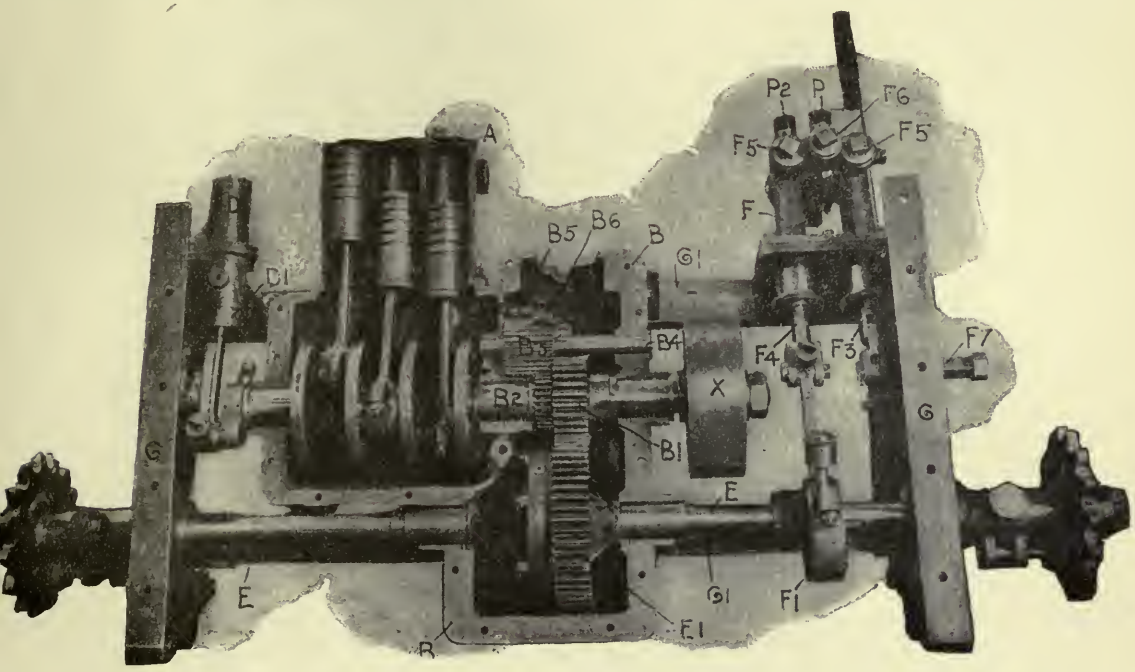


Fig. 168.—View of Engine of Miesse Steam Car.

itself consists of three parallel, horizontal, single-acting cylinders, fitted with mushroom valves which are operated by cams. The crank shaft has its three crank pins arranged at angles of 120° from one another, and the power is transmitted through a pair of spur wheels to a differential gear enclosed in the same casing with it. The differential gear is mounted upon a counter shaft lying across the frame of the car, from the ends of which side chains pass to the rear wheels. The exhaust steam from the engine is led to a radiator in front of the car, and any condensed water, as also any uncondensed steam passing through it, is led back by a pipe to the water tank.

The main frame is rectangular, and is built up of wood, stiffened with steel flitch plates and corner plates. It is fitted with five cross members of channel section, two of which carry the boiler beneath the bonnet in front; one is beneath the dash, and the other two support the fuel tank and the water tank at the rear. The engine is carried in the centre of the frame on two cross channels, which are rigid with brackets

bolted to the frame. The cylinders are cast in one piece, and are bolted to the crank chamber.

The engine itself, together with the differential counter shaft driven by it and the water and air pumps, is seen in Fig. 168. The cylinders have in this illustration been cut in half in order to show the pistons in place, and the pistons are not fitted with their rings. The upper portion of the oil-tight casing enclosing the cranks and other moving parts has also been removed, so that they are exposed to view. A complete cylinder casting A is shown in Fig. 169, with the inlet valves A_1 and the exhaust valves A_2 in place. Removable caps fit above each valve, and the steam and exhaust pipe connections are made to each set of valves at A_3 and A_4 respectively. On the latest castings the pipes are fixed by flange joints instead of with threaded unions as before. The cylinder casting is by no means an easy one to make, and has several awkward cores in it. The steam enters through ports on the upper sides of the cylinders, and is led out to the

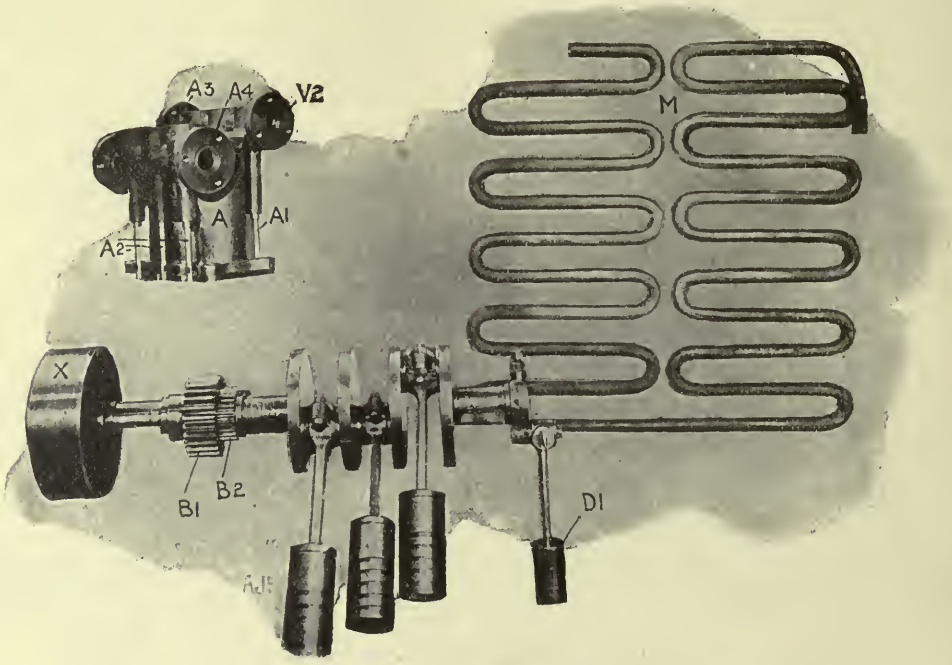


FIG. 169.—Cylinders and Pistons of Miesse Engine and one Section of Boiler.

exhaust valves on the under side. The casting is bolted to the casing B, which encloses the cranks and the gearing.

The crank shaft is made from a single forging, and is in one piece from end to end. The crank pins, which are arranged at an angle of 120° from one another, are machined out in such a way as to leave circular discs each side of them. The shaft is supported in three special metal bearings, and has a separate crank bolted on its one end for working the air pump D, the brake drum X being fixed to its other end. Two spur wheels B_1 and B_2 are mounted upon it between the two bearings on the one side of the cranks. The wheel B_1 meshes with a corresponding wheel E_1, which is fixed to the shell of the differential gear; the differential is supported on each side by bearings formed in the casing B. The casing is bolted down to two cross channels G_1, which are fixed at each end to the brackets G, by which this portion of the mechanism is secured rigidly to the side members of the frame. The brackets G carry the outside bearings for the two halves of the counter shaft E, the distance rods to the back axle, and the transverse shaft which operates the side brakes.

The gear wheel B_1 is approximately half the diameter of the wheel E_1, and therefore the counter shaft E is driven at about half the engine speed. The spur wheel B_2 gears with a wide-toothed wheel B_3, mounted on a lay shaft in the box, and this wheel drives the two cam shafts which operate the inlet and exhaust cams respectively. The cam shafts are formed out of steel rods, the cam faces being cut into their surfaces. The shafts slide freely longitudinally in the crank chamber casting, and are therefore easily removable. Each cam shaft has a spur wheel on its one end, the wheel B_5 on the exhaust cam shaft being seen in Fig. 168. The spur wheel B_3 is of sufficient width to allow for the full longitudinal movement of the cam shafts and their spur wheels, so that it remains in mesh with the wheels at all times. The cam shafts are simultaneously moved longitudinally by a fork piece B_9, which engages collars on both of them, and the forked piece is itself operated by a lever arm, which is not shown in Fig. 168, but is fixed to a vertical spindle. The inlet cams are so shaped with varying profiles that they have a neutral longitudinal position in which they fail to open the valves at all. When slid in one direction they cause the engine to run forwards, and in the other direction to run backwards. For the forward direction they not only open the valves at the beginning of the outward strokes of the pistons, but they allow them to close later during these strokes according to the distance the shaft is moved, thus varying the "cut-off." The exhaust cams are shaped so that they hold the exhaust valves slightly open when in their neutral position, and allow for running backwards and forwards when slid longitudinally in one direction or the other. The object of holding the exhaust valves open when the reversing lever is in its neutral notch is to allow the engine to run freely when the car is running downhill; the pistons can then move backwards and forwards in their cylinders without producing any vacuum.

The air pump D is fixed to one of the brackets G; its piston D_1, connected with the crank shaft, is shown in Fig. 169. The feed-water pumps F, as shown in Fig. 168, are fixed to one of the brackets G, and the plunger F_4 of the one pump is operated by the eccentric F_1 on the counter shaft E. The plunger F_3 of the other pump is operated by the hand lever F_2, shown in our illustrations of the chassis; the lever fits over a squared portion of the shaft F_7, to which the plunger F_3 is connected by a lever arm. The two water pumps have separate suction valves beneath them, and they also have separate delivery valves, which are arranged beneath the screw caps F_5. The water passes from the pumps through the pipe connections P_2 to the hand-controlled bypass R, and it passes through an additional delivery valve beneath the cap F_6, and through the pipe fitting P, in order to go (1) to the generator, (2) to the relief valve S, and (3) to the safety valve Q. The valve beneath the cap F_6 thus forms a non-return valve between the boiler and the pumps, and prevents the boiler pressure from forcing water or steam back through the bypass and the condenser to the water tank.

The cylinders of the 10 horse-power engine have a bore of $1\frac{15}{16}$ inch and a stroke of $3\frac{1}{8}$ inches; those of the 16 horse-power engine have a bore of $2\frac{5}{16}$ inches and a stroke of $3\frac{1}{2}$ inches. The gear ratio between the crank shaft and the road wheels is approximately 4 to 1, the counter shaft running at about half the engine speed, and the chain wheels on the 10 horse-power car having 15 and 35 teeth respectively, and on the 16 horse-power, 15 and 30 respectively. It will be noticed that the pistons are provided with five rings, and that they are unusually long. Very little steam appears to find its way past them, and any that does so is allowed to escape from the crank chamber through a down tube fitted to its removable cover.

One of the sections M of the boiler is shown in Fig. 169. There are sixteen of them in all, and they are laid horizontally above one another with the zigzag coils of alternate layers at right angles to the others. The tubes vary in thickness, and are made of solid drawn weldless steel. They are connected together in series of four layers by outside unions. The joints appear to be thoroughly satisfactory, and are remarkably strong.

The different layers of the generator are connected together in such a manner that

the water enters the bottom one first. It then finds its way up through several of the sections before being led across some of the central sections to flow up through the upper sections. After passing through the top sections it is brought down again to the lowest of the intermediate layers, through which the steam then passes upward before being led to the engine. The lowest tubes may thus be roughly regarded as feed-water heaters, and are therefore not liable to become burnt under ordinary working conditions. The top layers receive less heat from the burner, and may be called the steam-raising coils. The intermediate coils may in the same way be looked upon as a super-heater portion of the generator. The tubes vary in thickness, although the external diameter throughout is $\frac{3}{4}$ inch; those at the bottom have an internal diameter of $\frac{5}{16}$ inch, and the superheated coils of $\frac{7}{16}$ inch. In the 10 horse-power generator the total length of tube is about 200 feet, and in the 16 horse-power size about 300 feet. Owing to the difficulty of cutting the threads on the ends of this tough tubing with ordinary dies, all the screwed union joints are made by thickening up the tube ends and screwing in the lathe, afterwards being welded to the main coils by a system of oxyhydrogen gas. The external steam piping is very short, and is also of the same material as the generator tubes; any joints are made by flanging the tube itself inside the unions. Weldless steel tubing is also employed throughout the car for the fuel, air, and water pipes.

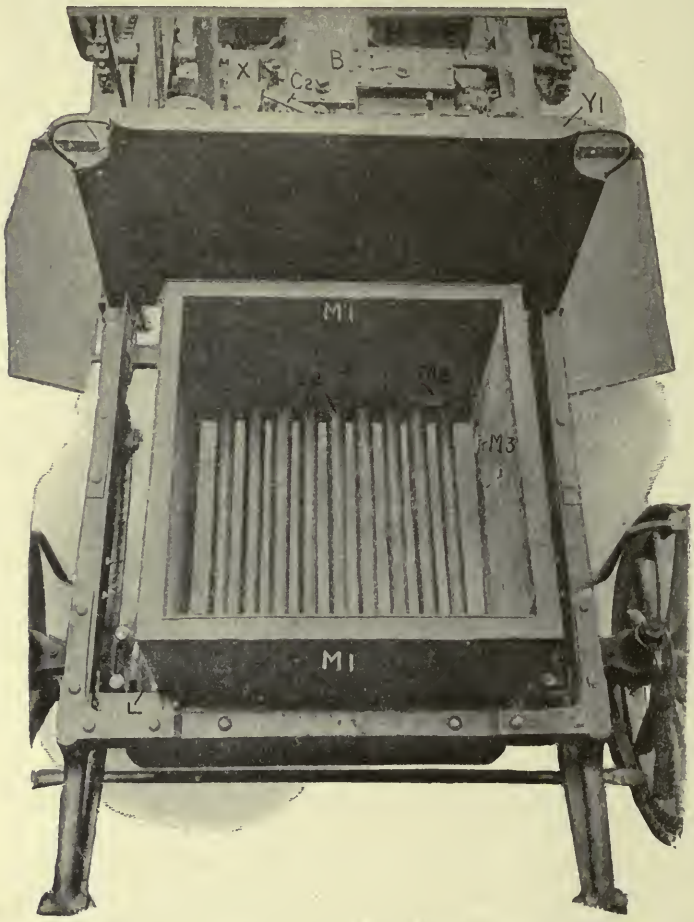


Fig. 170.—Position of Boiler in Miesse Steam Car.

The generator is enclosed in a special casing M_1, which is seen in place in Fig. 170. It is built up with an inner and outer sheet of steel, which are held together by channel steel frames top and bottom. The space between the metal sheets is filled up solid with layers of asbestos. The casing is fixed to two cross channels of the main frame. In the 10 horse-power vehicle it is 1 foot 8 inches long, wide, and deep. The 16 horse-power casing has the same depth, but is 2 feet 1 inch long by 2 feet 1 inch wide. The cover above the generator tubes is formed of a plate having three long rectangular holes in it. The plate is made to form the bottom of a horizontal flue, a second bent plate being fixed above it. This flue runs out through the bonnet in front, and is connected with a vertical flue passing down between the generator casing and the dash, the burnt gases from the generator passing out through it beneath the car. The generator is tested to a pressure of 1200 lbs. per square inch.

The vaporiser rests directly on two of the main burner tubes. The oil enters one end of the vaporiser, passes through the various spirals, and emerges at the other end as vapour. The vaporiser is placed in line with a hole M_2 in the casing M_1, through which the flame of the pilot light is introduced. The vaporised oil passes through the hand regulator to the burner jet. The gas formed in the coil J_3, when starting, has therefore but a short distance to go to the burner. The vaporiser is made of the same material as the generator tubes. It has an internal bore of $\frac{5}{16}$ inch, and an external diameter of $\frac{9}{16}$ inch. An inspection hole M_3 (Fig. 170) allows the operator to see when the coil J_3 is sufficiently heated by the pilot light to permit the paraffin cock J to be opened.

A good idea of the burner is obtained in Fig. 171, where the nozzle K, through which the vaporised oil passes into it, is shown withdrawn from the mixing pipe L. This pipe L is open to the air at the end into which the nozzle K projects. The pipe leads into a chamber L_1, which is made in two parts so as to allow the burner tubes L_2 to be fixed into it, and to permit of cleaning out when necessary. The tubes L_2 are perforated as seen in the illustration, the two external tubes having but one row of holes in them, and the other tubes having two rows. The mixture of gas and air issues out of these holes at an angle of 45°, and the flames from each adjacent tube strike one another and cause the heat generated to be very equally diffused. The burner is placed in the bottom of the boiler casing. It is slid in through holes which are bored for each of the pipes L_2 in the front and the back of the casing. It is therefore put in place in just the same manner as an ordinary drawer. The mixture supply tube L lies outside the generator casing. The central tube L_2 is somewhat longer than the others, so that it projects through at the back of the generator casing. It is slotted near its end, so that the burner may be fixed in place by a wedge-shaped cotter key fitting in the slot. All the tubes L_2 are, of course, closed at their rear ends. The 10 horse-power burner has seven tubes, and the 16 horse-power has nine tubes. Even the smaller burner has over a thousand small holes in its tubes. The hole through the nozzle K is extremely small, being only about $\frac{1}{16}$ inch in diameter.

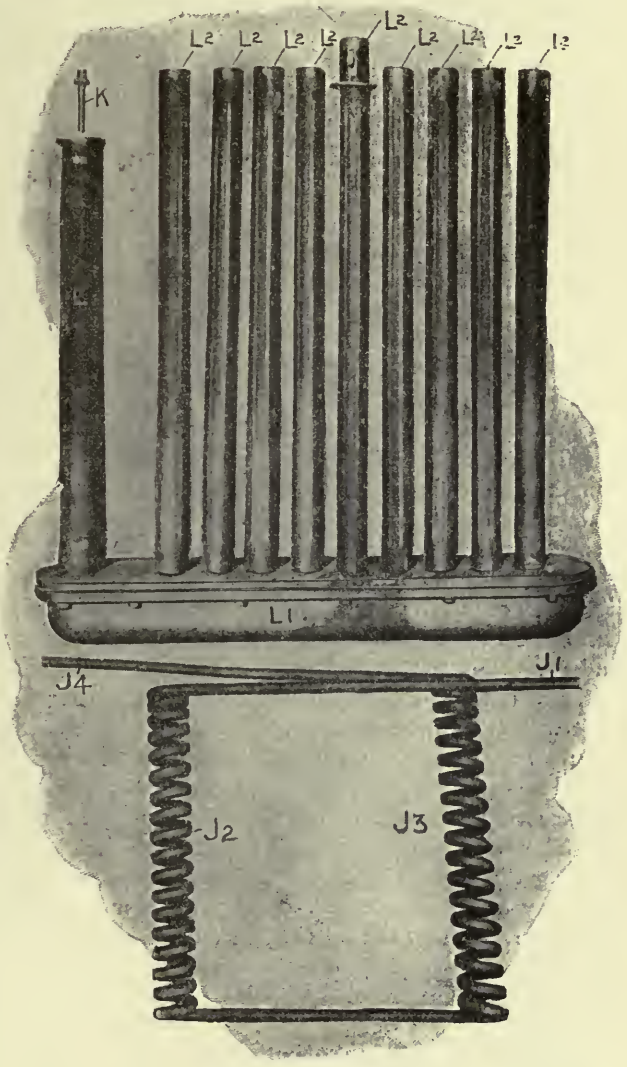


FIG. 171.—View of Miesse Burner and Vaporising Coils.

It will be noticed that no attempt has been made to introduce automatic controlling devices of any kind, and that it is chiefly in this respect that the Miesse car differs from others in which steam generators of the flash type are employed. In practice the speed of the car is for the most part regulated by varying the steam pressure, and this is done almost entirely by varying the quantity of water which is admitted to the generator. The heat of the burner must, of course, be regulated to a certain extent in accordance with the amount of power which is required. When the car is standing for periods longer than a quarter of an hour, the pilot light cock is turned on and immediately lights itself from the main burner, which is now turned out, and *vice versâ* when ready to start car again. When running, the driver can ascertain whether the boiler tubes are insufficiently hot, or are overheated, by noticing the rapidity with which the steam pressure rises in relationship to the quantity of water delivered to the generator. If very hot the pressure will rise extremely quickly, and if not hot enough the reverse will be the case. When unexpectedly brought to a standstill by traffic, the steam pressure is apt to rise rapidly, and it is for such occasions as these that the relief valve on the steering pillar is provided, and that the safety valve is fitted. The steam pressure normally varies from about 150 lbs. up to 400 lbs.

The throttle valve fitted is so arranged as to be held open normally by a spring, and it can only be closed by depressing a foot pedal. This valve is intended for use when wishing to slacken speed or stop momentarily, and is for the most part intended to obviate the necessity for moving the reversing lever to zero and back again ; it thus saves trouble and avoids unnecessary wear and tear on the cams.

The only part of the system which is automatic is the air system for maintaining a constant pressure of fuel. The pressure is initially obtained by an ordinary tyre pump, which is connected to a nozzle provided for the purpose on the dash, and already mentioned in this article.

It is very important that the vaporiser coil should be thoroughly heated by the pilot light before attempting to start the burner with its ordinary fuel. The operation of heating up takes something over five minutes to perform, but should not be hastened unduly, because the burner is liable to smoke if the coil is insufficiently hot. With ordinary care, however, no smoking of the burner will occur, and troubles of carbonising in it will at the same time be avoided. When first turning on the paraffin the cock should be very slightly opened, otherwise "surging" may result. The burner appears to work extremely well, and to give an enormous amount of heat ; the simplicity of its construction is also a further feature strongly in its favour, and it is very quiet.

The hand pump for forcing water into the boiler is only intended to be used when starting the car. The cars are somewhat heavier than petrol vehicles of similar size ; but they appear to have ample power for all ordinary purposes. They are well and strongly built, and the bearing surfaces throughout are large.

THE STANLEY ENGINE BOILER

This engine has a tubular boiler with an automatic regulating oil burner. The engine itself presents no features of novelty, but the boiler is interesting as an example of the tubular type compared with the flash boiler described in the last example of cars of small weight.

The boiler (Fig. 172) is a seamless copper tube 14 inches diameter, 13½ long, and $\frac{1}{16}$ inch thick ; the tubes of the boiler are ½ inch in diameter and about 3½ thick. The tube plates are of steel, and are all turned up in a bunch to the same diameter. The holes are punched and afterwards reamered out to size. A blow-off is tapped into the lower tube plate, and the steam pipe hole is tapped into the upper tube plate.

This entire boiler is held together by friction only, no rivets, bolts, or screws being used, and no expanding, in the ordinary sense of the word, being done. The boiler

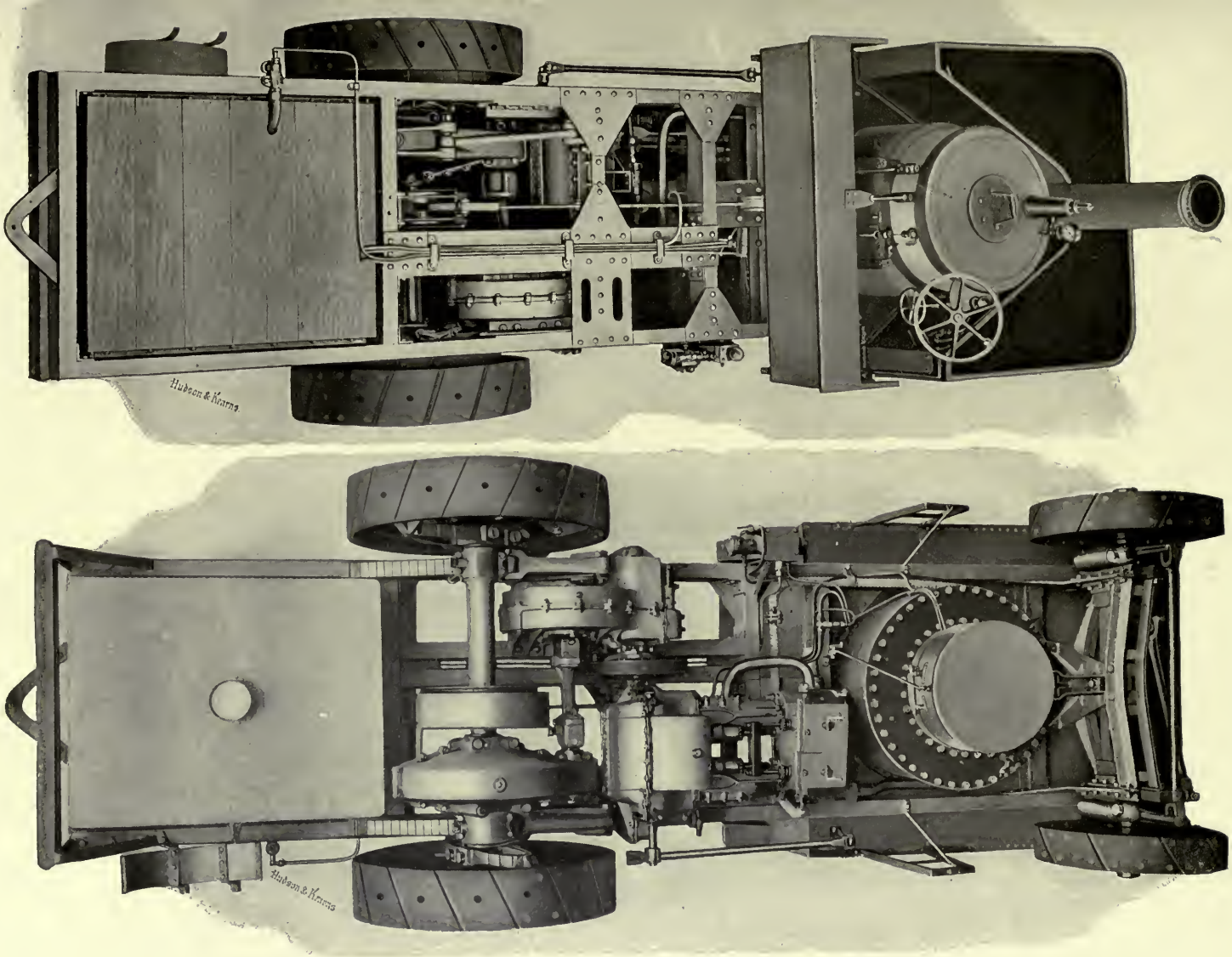


PLATE V.—STEAM ROAD VEHICLE (TOP VIEW AND UNDER VIEW).

heads or tube sheets are held to the shells by machine steel rings $\frac{7}{8}$ inch wide by $\frac{3}{8}$ inch thick, electrically welded exactly to uniform diameter; not bored inside after welding, but simply smoothed at the weld enlargement with a file on the inside only, the outside and edge swell of the weld not being removed. This makes it certain that the weld will be the strongest place in the ring.

To assemble the boiler, the shells are first clamped in a ring fixture, and slightly expanded by hand with a wooden mallet at each end, so that the heads can be slipped in to place inside the shells, leaving about $\frac{1}{16}$ inch of shell length projecting beyond the outside of the heads. Then the heads are located by slipping in tubes at intervals round the outer tube circle, and expanding them by lightly driving a taper tool in the tube end. This has the same taper as the tube sheet reamer, about $\frac{1}{4}$ inch in 6 inches.

Then the remainder of the tubes are put in place and expanded the same way, and lastly, the outer edges of the shell are turned inward a little by hand with a wooden mallet, so that the rings will slip on readily. This completes the first operations on the boiler, which then goes to the smithy, where the machine steel head holding rings are heated in a Brown and Sharpe case hardening furnace, and are slipped over the boiler shells down to a gauge ring clamped on to the shell, and allowed to cool. This is all that holds the heads into the shells. The end pressure on the heads is abundantly resisted by the tensile strength of the copper tubes, expanded to the taper of the tube plate holes.

FIG. 172.—Stanley Boiler.

To apply the steel piano wire the boiler is chucked by one head ring in a 4-jaw chuck in an ordinary engine lathe, and revolved, the wire being led through an eye in a steel standard bolted to the lathe carriage, which is driven by the lead screw, so as to wind the wire close on the shell under a heavy tension. The wire is fastened to a pin in each head ring, and is no longer soldered to the shell.

From the winding lathe the boiler goes to the testing pump, to which it is connected, and 600 lbs. pressure is put on with a hand pump. If any tubes leak the 60° expander is applied with light blows of the hand hammer. The boilers are commonly tight at first trial.

The common practice for small fire tube boilers is to use a drawn steel shell—one head integral and the other head cupped, and riveted in with copper fire tubes. Copper expands about twice as much for each degree of added heat as does steel, with the result of making the tubes leak in the tube plates, because they are longer than the steel shell when both are heated. The Stanley boilers have shell and tubes all copper, so the tubes never leak.

The boiler is clothed with an inch thickness of asbestos, secured by wide brass bands, only about $\frac{1}{100}$ inch thick, held by passing one end through a wire eye fastened to the other band end, and folding the inserted end over. This fastening enables the band to be drawn tightly on the asbestos, as with a band and buckle, and the bands can be removed readily, and may be many times reapplied without injury. An inch of asbestos effectually prevents heat radiation. The boiler is located under the seat, and is surrounded by the water tank, which is rectangular in form on five sides to

fit the car body, but is hollowed out on the front vertical side to take the boiler. The smoke box is of galvanised iron, and the flue is led horizontally to the rear on the top of the water tank, and is then carried downward to about ½ inch below the bottom of the carriage body at an angle, so that the smoke and the exhaust will clear the rear axle, as discharged downward. Stanley first used two draught openings from the smoke box —one leading upward and the other downward. The scheme was to use the upward exit for firing up and standing, natural draught, and to employ the down draught when the machine was running, and the exhaust steam could be made to force the draught downward. Experiment showed that a natural down draught could be established without the exhaust jet, and the upward smoke opening is no longer used.

Fig. 173 shows the Stanley burner. BB, baffle plates which carry the air downward under the burner tubes and prevent a side wind from blowing out the flame when reduced by the steam diaphragm regulator. T, vaporised fuel supply to main burner tubes. P_2, pilot burner needle valve. The tubes T are brazed together and pass horizontally through the burner frame, under the bottom tube plate of the boiler. The horizontal tube to the main burner is loosely filled with twisted wires. That to the pilot burner is loosely filled by an iron rod to hold heat. Both horizontal tubes pass over the pilot burner, and are so kept hot while the main burner is shut off.

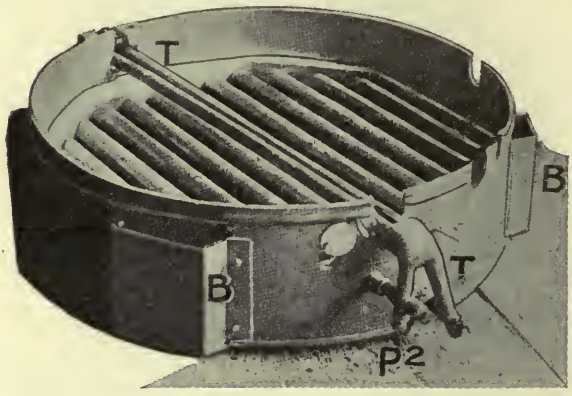


Fig. 173.—Stanley Burner.

The pressure of the steam acting on a piston against a spring can be made by means of a needle valve to open or close the petrol jet, and thereby regulate the pressure automatically. When the pressure rises the piston pushes forward the valve against the spring and closes the oil supply; and when the pressure falls the spring overpowers the piston and opens the valve.

There is a water-feed pump operated by the engine, and also, one which can be worked by hand.

For light cars, speaking generally, the steam engine has not been so widely and generally adopted as the petrol car; although they have some advantages, in running smoothly and quietly, without smell, and have no elaborate mass of gear wheels. If the water supply is attended to, there is little else requiring care; but the water requires to be carefully attended to both in quantity and quality. A glance at the boilers, whether flash boiler or tubular boiler, will show that they are not to be filled with any kind of water. The water should be soft and pure. Any scale forming in these small boilers is a serious matter. No provision for cleaning them out can be made. There is no room for that, so that users of the boilers must preserve them from water which forms sediment or scale.

The steam turbine has been tried on cars, but without condensing water steam turbines are far from economical of steam.

For heavy traction the steam prime mover still holds the field and has much in its favour, although the heavy boiler still presents a considerable drawback. Heavy road vehicles are made to earn money by carrying goods on common roads, not of the best, and in all weathers. Hence their design is a totally different matter from that of a sporting or pleasure vehicle. On this subject Mr. Clarkson's Society of Arts paper may be read, and we have here made some extracts therefrom. Each of the details must be of

the most permanent and substantial construction;—and only the best material, design, and workmanship is good enough.

As the strains brought to bear on the machinery are often very severe and far beyond their normal load, the factor of safety must be ample in order to ensure that a considerable overload does not produce any permanent result, or the first time a car gets into trouble its character will be injured for life.

Another specially important consideration in the design of the machinery for public service cars is to reduce as far as possible the amount of time which it is necessary for the car to receive attention, not only when in commission, but also in the garage, that is, in cleaning and preparing for commission. It is therefore a *sine quâ non* that, as far as possible, every bit of machinery shall be enclosed within a dust-proof and mud-proof oil-retaining case; this at the same time obviates the necessity for the cleaning of the machinery; for to do this thoroughly occupies a good deal of time every night in the garage, and there is some risk of its not being done in the most thorough manner.

THE CHELMSFORD STEAM CAR

The following are some details of construction of vital parts on the "Chelmsford" steam car:—

In a steam car there is no necessity for a change-speed gear and its attendant complication, the whole of the change of speed being done by the regulation of the supply of steam to the engine.

The machinery of a steam car comprises the engine, differential and transmission gear and pumps. The design of the "Chelmsford" set of machinery has been carried out in order to embody all these essential parts in one complete mechanism, which can be applied to, or, if necessary, removed from a car as a complete unit; the advantage of this arrangement is that should the engine ever suffer serious injury, it would be perferable to remove it completely from the car for repair, at once substituting a stand-by engine in order to put the car again in commission while its engine is being overhauled.

The body is constructed largely of aluminium. The side windows are arranged so that their upper halves can be folded down when desired, and there are also two windows in front, which when opened allow the passengers to communicate with those on the front seat. The car is fitted with artillery wheels shod with 3-inch solid rubber tyres.

Referring to Figs. 174 and 175, the boiler is placed in front, and the flue from it, which has an oval section, passes up centrally through the roof. On either side of it curved glass windows are fitted; they can be opened or closed at will. The boiler is of the vertical fire tube type, solid drawn steel tubes being used. It is tested to a pressure of 750 lbs. to the square inch, and its normal working pressure is 250 lbs. It is heated by one of the Clarkson burners, using ordinary paraffin oil, and it is automatically regulated by the boiler pressure. The oil tank holds 24 gallons, and is fixed at the rear beneath the frame, a gauge enabling the level of oil to be seen at a glance. The oil is pumped from this tank to a pressure receiver in the front of the car; this receiver contains a certain amount of air which acts as a cushion and as a reserve of energy for forcing the oil to the burner. A relief valve on the oil delivery pipe is set to come into operation at the desired pressure, and to thus return any surplus oil back to the suction side of the pump. The automatic device which regulates the burner is not of the diaphragm pattern, but contains a small plunger which is operated upon by the steam pressure against the action of a spring. It closes down the fire to a minimum when the pressure reaches 250 lbs. per square inch, and it opens it up full at about 180 lbs. per square inch. A very neat burner is fitted beneath the front footboard for initially heating the vaporising coil of the main burner. It enables the same fuel to be used for this purpose, and avoids the use of alcohol or petrol entirely.

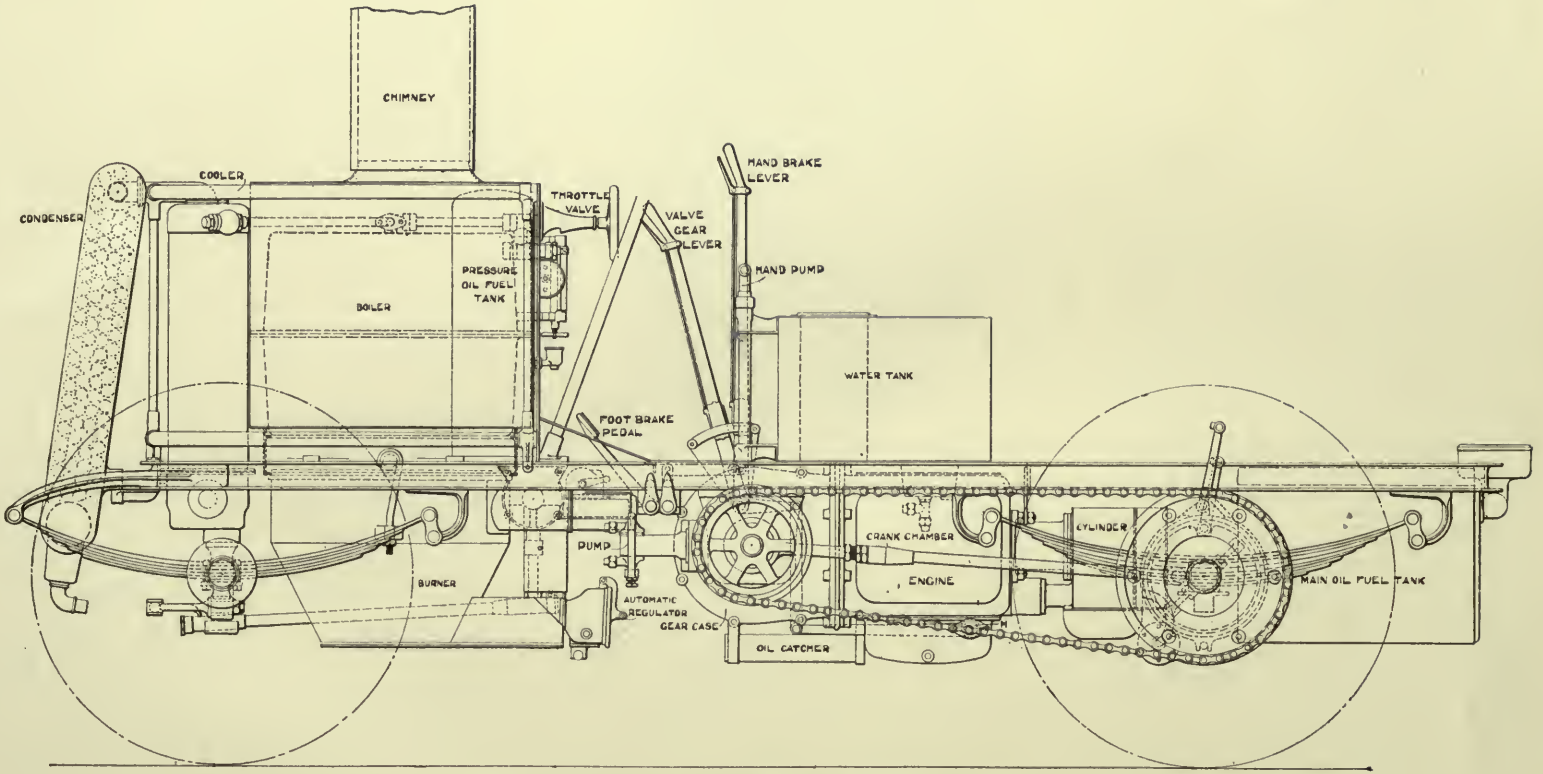


FIG. 174.—Elevation of Chassis of "Chelmsford" Steam Car.

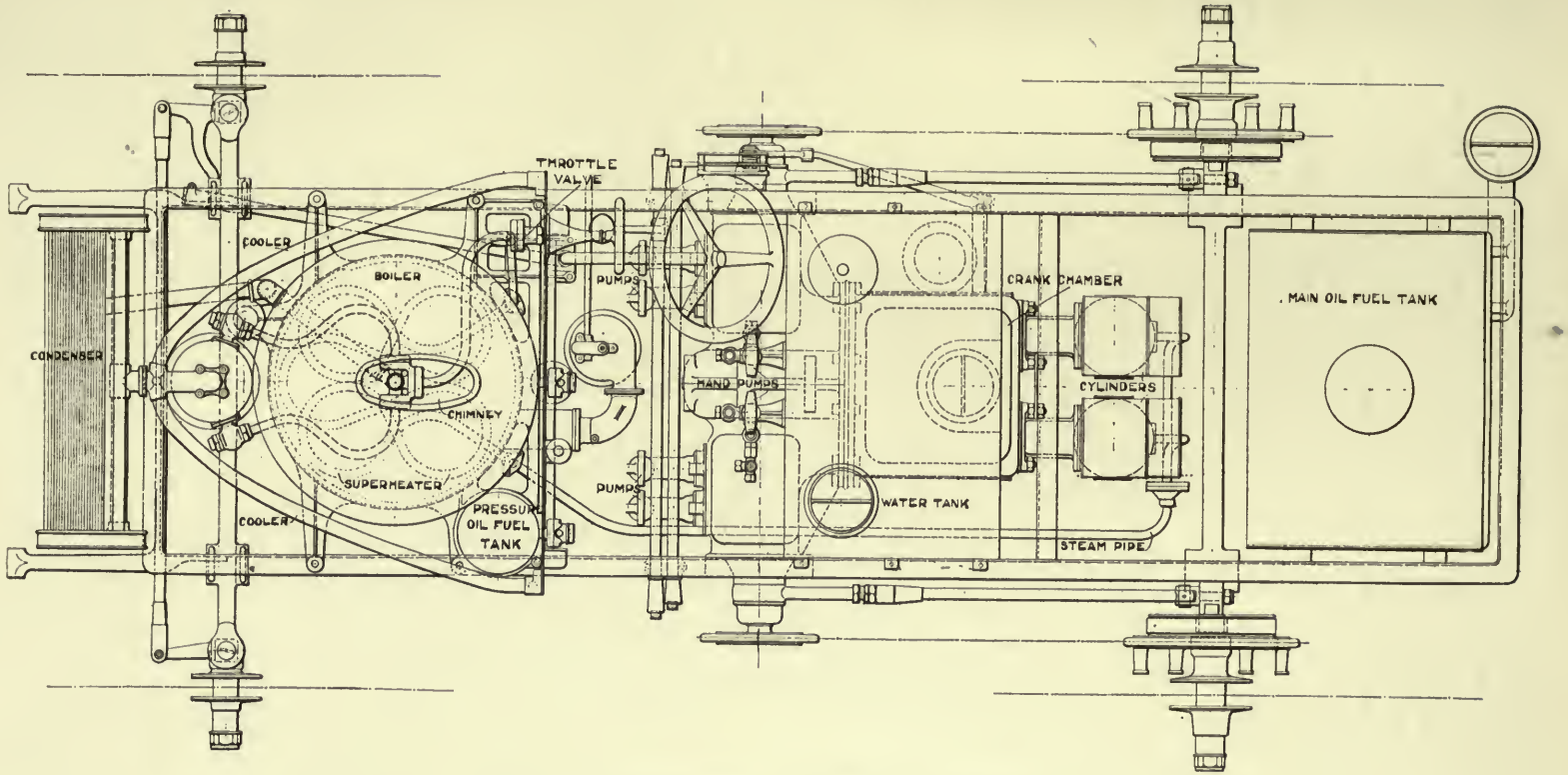


FIG. 175.—Plan of Chassis of "Chelmsford" Steam Car.

The water is carried in a tank, which is placed beneath the seats in the main portion of the body, and which project forward beneath the front seat. The water is pumped by a mechanically operated pump into the boiler, and the driver regulates the quantity delivered to it by a bypass.

The engine consists of two double-acting cylinders having a bore and a stroke of 4 inches. It develops 12 horse-power, and is of the horizontal pattern. It is fixed centrally beneath the floor, with its cylinders projecting to the rear. The crank chamber is entirely enclosed, and the differential gear of a transverse counter shaft is also arranged inside it. The slide valves are placed beneath the cylinders, and are operated by "Joy" valve gear. The power is transmitted from a steel spur wheel between the two cranks to a phosphor bronze wheel surrounding the differential gear. The transverse counter shaft is mounted in four double-ball bearings, in which ½-inch balls are used. Four separate pumps are driven by the counter shaft; one of these is a feed-water pump for the boiler, another circulates the oil which lubricates the moving parts of the engine and its gear, another pumps the condensed water back from the condenser to the main tanks, and the fourth pumps the paraffin from the main tank to the feeding pressure tank. The counter shaft carries sprocket wheels at each end, from which side chains pass to the rear wheels in the usual way. These chains are exceptionally long, and are of the roller type. Swinging distance rods are fitted as usual, provision being made for tightening the chain when necessary.

Separate exhaust pipes are led from each cylinder, one on each side of the car. They take the exhaust steam through feed-water heaters to the upper tube of a V-shaped (in plan) cooler, which forms the front of the bonnet. The steam is thus led into both ends of this tube, and some of it is condensed in this first cooler. The bulk of the steam, however, passes through from the centre of this tube to a large condenser which is carried in front of the car. Here the greater part of the steam is condensed, and the water finds its way to a drum placed beneath. A small pipe also lets any condensed water from the V-shaped cooler go to the same drum, and the pump on the counter shaft takes this water back through two filters into the water tank.

The filters remove the greater part of any oil that may find its way into the condensers, but a sponge box is also provided in the water tank itself, and the sponges appear to effectually remove or absorb any traces of oil which may be left. The lid of this sponge box, as also that of the different tanks, are of large size, and are ingeniously made so that they can be removed in a moment.

All the steam pipes are made of weldless steel, the ends being spun over in order to allow substantial face joints to be made. A pressure gauge is mounted in the centre of the dial-board; it has duplicate scales and needles for recording the steam pressure, and a needle and scale for indicating the pressure of the fuel feed. The speed of the car is for the most part controlled by the throttle valve, a mahogany-rimmed wheel of large size operating it. The wheel projects from the dial-board immediately in front of the driver, near the water gauge. A shut-off cock, which enables the driver to cut off the fuel feed on its way from the pressure reservoir to the burner, is also placed near by. An aluminium lubricating tank, containing the special oil for the cylinders, is also fixed to the dial-board; it contains two small force pumps which are operated by a small projecting handle. They deliver a small quantity of oil to the two cylinders through pipes which enter the upper walls of the cylinders. In practice the driver forces a few drops of oil into them at intervals of about five miles. The oil is thus injected on to the upper side of the reciprocating pistons, and, as the steam ports are on the under side of the cylinders, the oil also lubricates the valves. A further advantage of placing the valves beneath the cylinders is that any water which may accumulate in the cylinders when the engine is at rest is immediately discharged down the exhaust pipe when starting.

A large side lever, which is fitted to the right of the driver, is connected with the

valve gear. It works in a notched quadrant and operates the reversing gear, besides enabling the driver to vary the cut-off in a forward direction of travel. Several "ahead" notches, a neutral notch, and a single notch for the reverse are available. Two hand levers project upwardly through the floor, and are connected with a fuel pump and a water pump. Either of these can be brought into play when required, so that when the lever is given a few strokes by hand oil can be forced into the pressure tank, or water can be forced into the boiler. These small auxiliary pumps are for use when the car is at rest, or for obtaining pressure in the fuel reservoir initially; they are not intended for use under ordinary running conditions.

The whole of the driving machinery is carried upon the main frame of the car, this being supported in the usual manner by semi-elliptic side springs front and rear. Two independent pairs of brakes are fitted, both operating direct upon the rear wheels, one being worked by a foot pedal in front of the driver and the other by a hand lever. One pair of brakes is of the shoe type, the shoes pressing against the inner surface of rings secured to the spokes of the wheels. The other pair are of the double-acting band type, the brake drums being fixed to the sprockets. In both cases the brakes on each side of the vehicle are interconnected by steel cables in such a manner that the pressure is equalised. The steering gear is of the "Ackerman" pattern. The average speed is about 16 miles an hour, and the fuel consumption has been found to work out at less than a penny a mile; the actual quantity of oil used has been found to be about one-sixth of a gallon per car-mile, and the oil now costs about 5d. per gallon. The water consumption, when not condensing, has been found to work out at 15 lbs. ($1\frac{1}{2}$ gallons) per car-mile, but, as has been stated, the 34 gallons carried is sufficient to run 120 miles; its normal working pressure is 250 lbs. It is heated by one of the well-known Clarkson burners, using ordinary paraffin oil, and it is automatically regulated by the boiler pressure.

The general arrangement of the mechanism is shown in Figs. 174 and 175; Fig. 174 being a side elevation, and Fig. 175 a plan of the chassis.

The main frame is rectangular in shape, and is constructed of channel steel, $2\frac{1}{2} \times 1\frac{3}{4} \times \frac{1}{4}$. The boiler, which is of the multitubular type, with vertical fire tubes, is fixed in front. The burner is carried immediately beneath it, and the lamp for initially heating the vaporising coil is so arranged as to be easily accessible beneath the floor of the front seat. The funnel is of oval cross section, and it projects up vertically from the bonnet; it is given this shape in order to prevent it from obscuring the view of those sitting in front. The main oil tank is carried at the rear, and is secured to the main frame; the oil from it is pumped into a pressure chamber which is mounted, as shown, behind the boiler on the left. This reservoir is made air-tight, and is of very strong construction. Its upper portion contains a certain quantity of air, and the oil is forced into it from beneath. Provision is made by which air can also be pumped into it by hand when desired, and two try-cocks are fitted in order to enable the driver to ascertain the level of the oil in it when he so desires. The relative space occupied by the air at a certain pressure is so calculated as to maintain a sufficiently high pressure for feeding the oil into the burner when the car is at rest, and when the oil pump is consequently not working. An auxiliary pump, which will be described later, permits the oil to be fed into this pressure tank by hand, and so replenish the supply if the car has at any time been left standing for an unusually long period with the burner alight.

The try-cocks project through the dial-board, and a cup is fixed beneath them to catch any oil which may be allowed to flow from them. This cup is provided with a wire across the top to indicate a certain level, and thus to allow a certain fixed quantity to be measured off into it. The bottom of the cup is fitted with a cock from which a pipe leads down into the starting lamp, and thus a definite quantity of paraffin can be fed into it without it being necessary for the driver to handle the oil in any way. As

will be shown later, it is then only necessary for him to throw a lighted match into the burner and to start a fan working.

The oil from the pressure tank flows direct to the burner through a stop cock, which is placed on the dial-board immediately in front of the driver. The burner itself is regulated by an automatic device which reduces the size of the flame when the steam pressure reaches a certain point, and automatically opens up the burner to its full power as the pressure again falls.

The engine is fixed in a horizontal position beneath the main frame, and the cylinders are of the double-acting high-pressure type; both the bore and stroke is 4 inches. They are bolted to castings, which enclose the stuffing boxes, and through them they are secured to the crank chamber. The crank chamber, as also a separate casting forming the main bearings for the crank shaft, is bolted to the casing, which encloses the differential gear and the transverse counter shaft. An oil reservoir is fixed beneath the casing, to collect the lubricating oil as it passes from the bearings. The two halves of the counter shaft carry four eccentric blocks for working the four mechanical feed pumps.

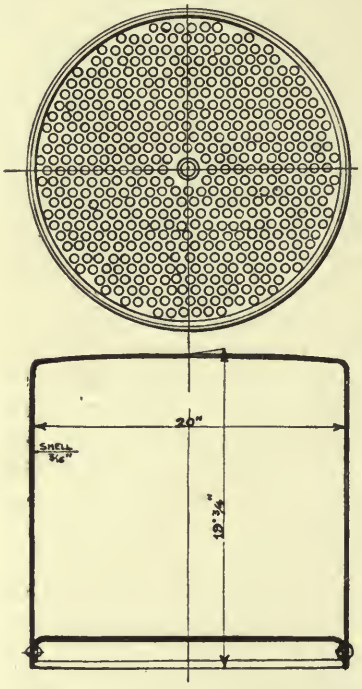


FIG. 176.—"Chelmsford" Boiler.

The exhaust steam from the engine is taken by two separate exhaust pipes to the opposite ends of the tube, which forms the top of a V-shaped cooler surrounding the closed-in front portion of the car. It will be noticed that the shape of this radiator resembles a V in the plan view, and that the top tube is connected with a parallel bottom tube by a large number of vertical wire-covered tubes. The steam is not compelled to pass through these vertical tubes, but a certain amount of it flows into them, and is thus condensed. The bulk of the steam flows through the connecting pipe into a condenser. This condenser has a large number of horizontal cooling tubes passing across it. The condensed water in both coolers finds its way into the drum at the lowest point of the system, the water of the V-shaped cooler passing down the pipe. Any uncondensed steam is led into the flue above the boiler, so that it passes invisibly away through the funnel.

The condensed water itself is pumped from the drum into the sponge box in the water tank. This sponge box is arranged immediately beneath the front cover, and is so constructed that it forms a kind of syphon; the sponge chamber itself is an open-ended vertical cylinder, which is mounted inside a second chamber, this latter being closed at the bottom but having perforations near its upper end.

The side hand lever is connected with the valve gear by a system of levers, and operates it through a rocking shaft H which lies across beneath the crank chamber of the engine. When the shaft H is rocked in its bearings it operates the reversing gear. The lever works in a notched quadrant which engages with a catch. The lever is therefore held rigidly in whatever position it is placed. It allows the driver to vary the cut-off of the engine when running in a forward position, and to reverse the direction of travel.

The foot pedal projects from the floor-board in front of the driver's seat, and is connected with side brakes of the band pattern, and the hand lever with brakes of the shoe type. The shoe brakes press upon the inside face of rims bolted to the wheels, and the band brakes operate upon drums which are rigid with the large sprocket-wheels. Each pair of brakes is so arranged as to have a compensated action on each wheel. It will be

noticed that the mechanical brakes operate direct upon the rear wheels, and that they are therefore available even if either of the side chains were to come off. Under the usual conditions the engine itself also forms a thoroughly effective means of stopping the car, for if the throttle valve is closed and the reversing lever is thrown over the engine acts as a pump, and the retarding action is sufficient to stop the car upon even steep hills.

The boiler itself is shown in vertical and horizontal sections in Fig. 176. The shell is made of steel, and is in one piece with the top plate. The bottom plate is flanged around its edge, and is riveted in place, as seen in the drawing. The tubes are of weldless steel; their external diameter is $\frac{9}{16}$ inch, and the thickness of the metal is about 22 gauge. There are about 512 tubes in all, and they are expanded into the upper and lower plates.

The boiler is provided with all the usual fittings, the water gauge being, as already stated, fixed on the dial-board, as also the duplicate pressure gauge. Twin safety valves are also provided.

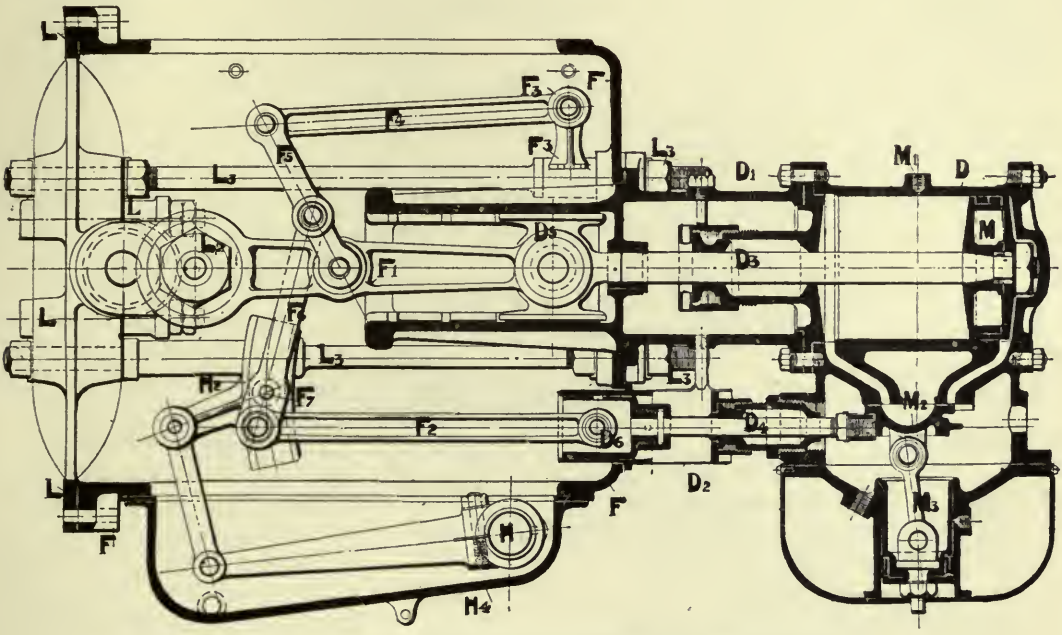


FIG. 177.—Sectional Elevation of "Chelmsford" Steam Engine.

The engine is shown in Figs. 177 and 178. The cylinders D are so constructed that they bolt to the chamber D_1, which surrounds the piston rod and the valve rod stuffing boxes D_3 and D_4. The cylinder oil used is a mixture of "Hecla" and graphite; it is forced by the pump fitting on the dial-board, which we have already described, through pipe S, which enter the top of the cylinders at M_1. The pistons M receive the entering oil, and carry it over the whole surface of the cylinders. The oil also finds its way through the ports at the bottom of the cylinders to the slide valves M_2, and any condensed water which may have formed in the cylinder also finds its way out past the valves directly the engine is started. The devices M_3 maintain the valves M_2 against their working faces, helical springs being used. The casting D_1 forms the guides for the cross-heads D_5 to work in, and it also receives the guide pieces D_6 for the valve rods D_4. The rods between the stuffing boxes and the guides are closed in by a light sheet steel cover D_2. The whole of the valve gear is enclosed in a casing F, the top of which is provided with a large inspection cover. This casing is secured in place between the casting D_1 and the

casting L, which forms the crank shaft bearings, by eight steel rods L_3. These rods give the required stiffness to the construction in the direction of the thrust of the engine, and the casing F itself serves the double purpose of assisting in making the engine rigid and of providing an oil retaining casing. "Joy" valve gear is employed, the details of which are clearly shown in the drawings. The brackets F_3 are held in place by the upper steel rods L_3. The brackets form rigid fulcrums for the swinging levers F_4, the other ends of which are pivoted to other links F_5. The double links F_5 are pivoted at their lower extremities to the connecting rods F_1, and they also carry fulcrum pins about which other double links F_6 are mounted. The links F_6 terminate at their lower ends about the connecting rod F_2, and are pivoted to it. These links F_6 have externally projecting pins F_7 at a short distance from their lower ends, and the pins F_7 fit into corresponding holes in blocks F_8, which in turn are free to slide in curved paths formed in guide pieces H_2. The guide pieces H_2 are themselves mounted in such a manner that they can be rocked about a centre, projecting sleeves which form a portion of them being carried in bearings H_3 in brackets which are fixed rigidly to the lower steel rods L_3. The connecting rods F_1 are thus caused to operate the connecting rods F_2, and therefore the slide valves M_2, but the manner in which they do so is determined by the position in which the guide pieces H_2 are set about the centre of the bearing H_3. When they are caused to rock about these centres the direction in which the engine runs is varied, and the degree of cut-off is also changed. This "Joy" valve gear is a well-known device, and its many advantages are fully recognised. In this particular adaptation of it the shaft H which passes across underneath the casing F is connected with the guide pieces H_2 in the manner shown in Fig. 177. The lever actually operating the gear is enclosed in the separate casing H_4, which is secured to the bottom of the casing F.

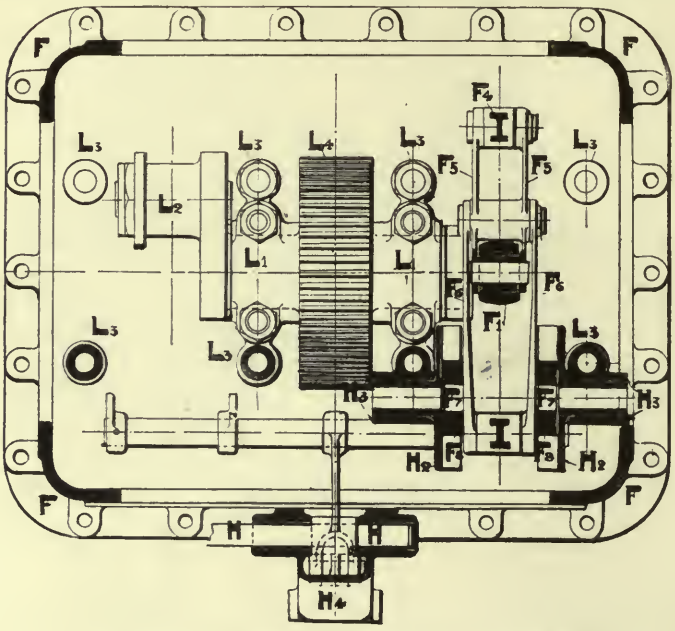


FIG. 178.—End View of "Chelmsford" Engine, with Cover removed.

The crank shaft is made with two overhanging cranks L_2 (Fig. 178), which are set at an angle of 90° to one another. It is carried in bearings L_1, which are formed in the casting L. A large steel spur-wheel L_4 is fixed to the centre of the crank shaft between the two bearings L_1. The power of the engine is transmitted by it to a phosphor bronze wheel of twice its size, surrounding the differential gear.

The differential gear G_3, together with its counter shaft, is shown in horizontal section in Fig. 179. As we have already stated, these parts are enclosed in the casing G. The casing itself is made in two parts divided vertically down the centre. It provides four double-ball bearings in which $\frac{1}{2}$-inch balls are used. The differential gear is of the spur-wheel type, and the shell is so made that the large phosphor bronze gear wheel G_4, through which it is driven by the engine, is bolted between the two halves.

The casing G is bolted to the main frame at each end, and the distance rods G_5, which pass down to the rear axle and serve for tightening the side chains when necessary, are fitted about its ends.

The two halves of the counter shaft itself carry eccentric blocks G_1 for operating four feed pumps, two on each side of the centre of the car. The shafts carry the sprocket-wheels

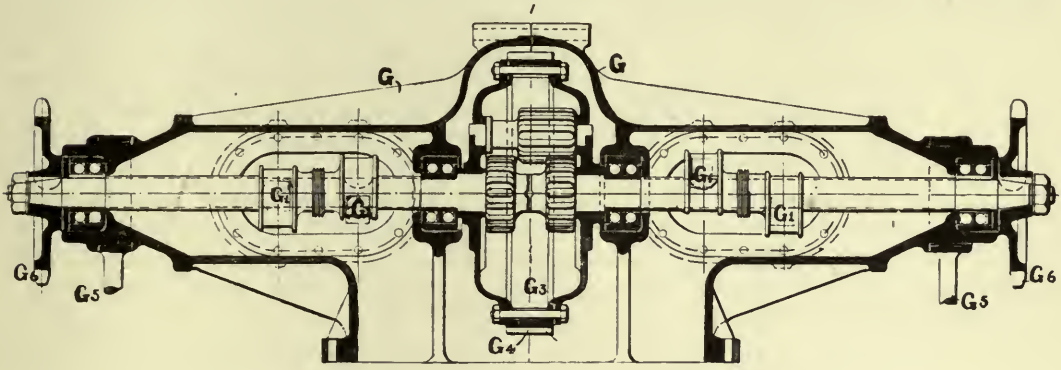


FIG. 179.—Sectional Elevation of Gear.

G_6 at their outer ends, and the power is transmitted from them to the rear wheels by roller chains in the usual way. The feed pumps which are driven from the counter shaft are fixed in a vertical position beneath it, and are secured to the casing G. The design of the pumps with their valves is shown in Fig. 180; the details of these are sufficiently clear, and do not, therefore, need further description. One of these pumps feeds water from the main tanks to the boiler, and another returns the condensed water from the

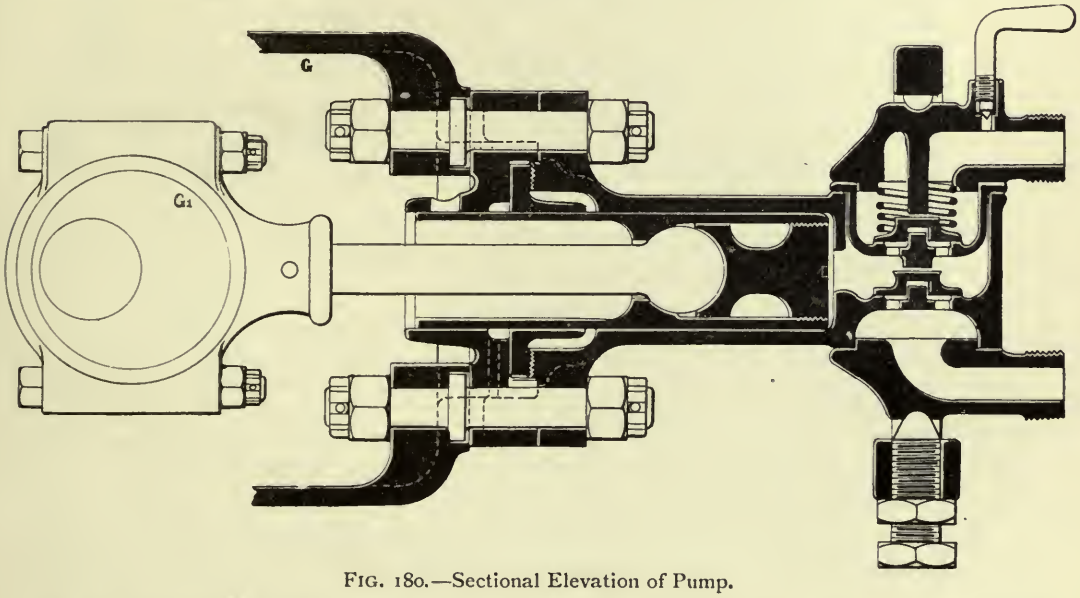


FIG. 180.—Sectional Elevation of Pump.

drum to the main tanks. Both these pumps have a stroke of 1 inch. The two other pumps are of similar construction, but the stroke given to them is $\frac{1}{2}$ inch; of these, one pumps the fuel from the main tank to the pressure tank, and the other supplies lubricating oil to the moving parts of the engine and counter shaft. This lubricating oil finds its way from the bearings to a reservoir beneath the differential gear, the pump then recirculating it to the various bearings.

The automatic fuel regulator is shown in Fig. 181 in section. The lower portion of this fitting forms a cylinder for the plunger N_1, a steam pipe P from the boiler being led to the bottom of it. The piston N_1, is fitted with a rod N_4 and a strong helical spring N_2, the latter tending to keep the piston down at the bottom of the cylinder. The upper portion of the fitting is secured to the lower portion by two steel rods, and the piston N_4 is connected by adjustable nuts with a cross piece engaging with a lever N_3. The lever is fulcrumed at the end of the piece N_5; the end is connected with the device which regulates the fuel and air supply to the burner.

As the pressure of the steam rises it lifts the piston N_1, compressing the spring N_2, and causes the lever N_3 to move about the fulcrum N_5, thereby reducing the size of the flame.

The vaporiser coil is made of steel tubing wound over with nickel wire to prevent the steel from oxidising. The flame of the starting lamp plays on one end of the vaporising coil.

The measured quantity of oil is taken up by the wick. A clockwork fan causes the lamp to burn, and concentrates the flame on the vaporiser coil. It takes about twelve minutes to get up steam from cold.

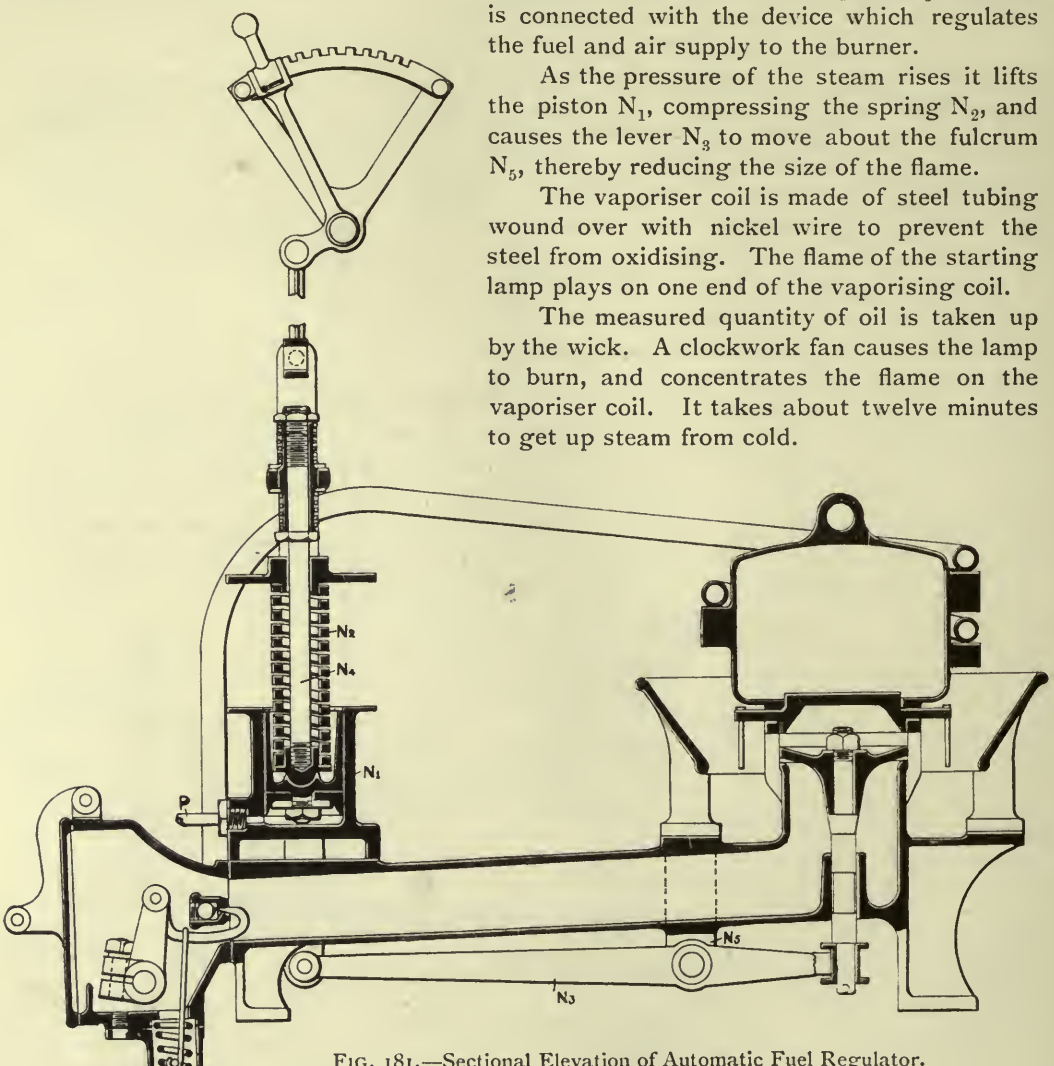


FIG. 181.—Sectional Elevation of Automatic Fuel Regulator.

The Chelmsford car is one of the few machines in which a successful condensing system has been combined with a fire-tube boiler. It appears to be thoroughly satisfactory; no trace of oil being detected in the feed water. The question of condensing on steam cars is an important and difficult one, and it has been pointed out that the presence of oil in the water tanks is inadmissible when any but a flash type of boiler is employed. The success of the Clarkson system is due to the care with which the cylinders are lubricated, to the special form of lubrication employed. Very little oil is necessary, and the mixture of graphite with the heavy hydrocarbon reduces the quantity of oil which is used, and allows of its complete separation from the condensed water. The

condensed water is drawn from the coolers through a strainer by the pump on the counter shaft, and is then forced by it through the filters to the sponge box.

The steam from the boiler is carried through a superheater before passing to the throttle valve; the superheater is of the gridiron pattern, and is M-shaped; it is placed above the burner. It ensures a supply of dry steam, the importance of which, particularly for automobile work, has been amply demonstrated during the last year or two.

The power and speed of the engine is, as a rule, regulated entirely by the throttle valve, but in special cases, such as when ascending steep hills, the cut-off should be varied. The average cut-off is set at about one-half, and it can be varied in a forward direction anywhere between zero and three-quarter stroke.

Reference has already been made to the automatic feed-water regulator for this car. The principle upon which it works is based upon the difference in temperature of the water and of the steam in the boiler. So soon as the water falls below a certain point the temperature of the device is increased owing to its being surrounded with steam instead of with water. It is so constructed that under these conditions it closes the by-pass communicating from the delivery pipe to the suction pipe of the force pump, and so compels the pump to feed the boiler. On the other hand, when the water rises above a certain level the converse effect is produced, the by-pass is opened, and the boiler feed is reduced.

One of the most important features of this vehicle is the care which has evidently been bestowed upon details. So far as the mechanical parts are concerned, they have been designed in such a manner as to be thoroughly accessible, although the working parts are, with but few exceptions, enclosed.

THE STRAKER STEAM VEHICLES

These vehicles are for heavy traction, and use good Welsh or other steam coal fuel. Fig. 182 is a view of the complete boiler; and Fig. 183 is a view of the boiler with external shell removed. Fig. 184 is a sectional elevation, and Fig. 185 a sectional plan of the boiler.

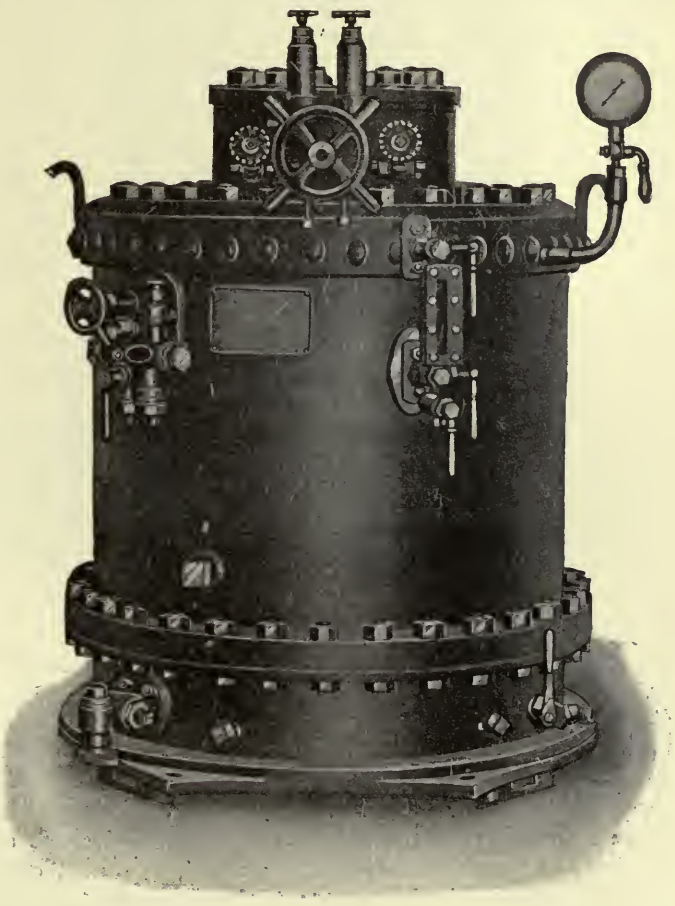


FIG. 182.—Complete View of Straker Boiler.

From Figs. 184 and 185, showing the sectional elevation and plan of boiler, the general construction will be easily understood. The design is based on the concentric and radial principle. There are four concentric shells, each pair of which form an annular water space, which are connected by a nest of radial

tubes, the interstices between them forming the flue space of the boiler. The hot gases generated in the furnace duly pass up through this flue space between the tubes, distributing heat in ascending. As the tubes are placed in echelon one over the other, complete baffling action takes place, so that on the hot gases reaching the smoke box the bulk of the heat is exhausted, which conduces to the best efficiency.

The disposal of the greater portion of the heating surface at right angles to the course of the passage of the gases assures the fulfilment of the first condition of economy. The boiler gives upwards of 30 per cent, more evaporative power on the same weight of fuel than any of the ordinary vertical fire or water-tube boilers with which we are conversant. A damper is fitted at the base of chimney for controlling the draught. Additional regulation may be secured by removing lid on firing hole, if required. This forms a ready means of controlling the steam production, and preventing blowing-off when the waggon may be standing.

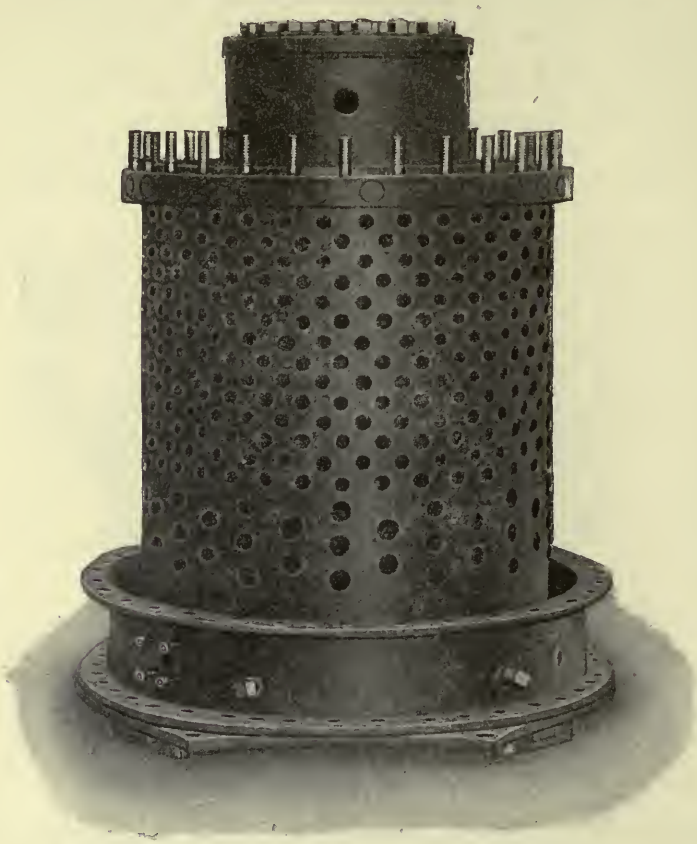


Fig. 183.—View of Straker Boiler, with Outer Shell removed.

The construction throughout being concentric and radial, provides for equality of expansion or contraction throughout, independent of the calls made upon the boiler; for this reason no trouble is experienced from leaky tubes due to unequal expansion. The extreme shortness of water tubes, and the efficient circulation in each one, conduces to freedom from incrustation, it being a generally recognised fact that the rate of incrustation is directly proportional to the length of the tubes. The tubes being disposed radially around one centre, the distance between them at the outer shell is greater than at the inner, permitting of a more rapid passage of hot gases at that end; hence the outer end is in a hotter portion of the flue space than the inner, which assures a perfect and rapid circulation in each water tube of the boiler, and a corresponding scouring out of deposit. Muddy deposit is removed from the outer water space by unscrewing the four mud plugs fitted to the outer shell, with the assistance of a hose and good stream of water, and without farther opening of the boiler.

The boiler will not require opening out for internal cleaning purposes at shorter periods than from three to six months, varying according to the water used. When necessary this is simply effected by removing the dome, which exposes the entire tube nest and enables each tube to be cleaned as required.

The inner water space is cleaned through the large tubes at the bottom of the nest, the joints on the inner water space being regarded as a semi-permanent job, which should

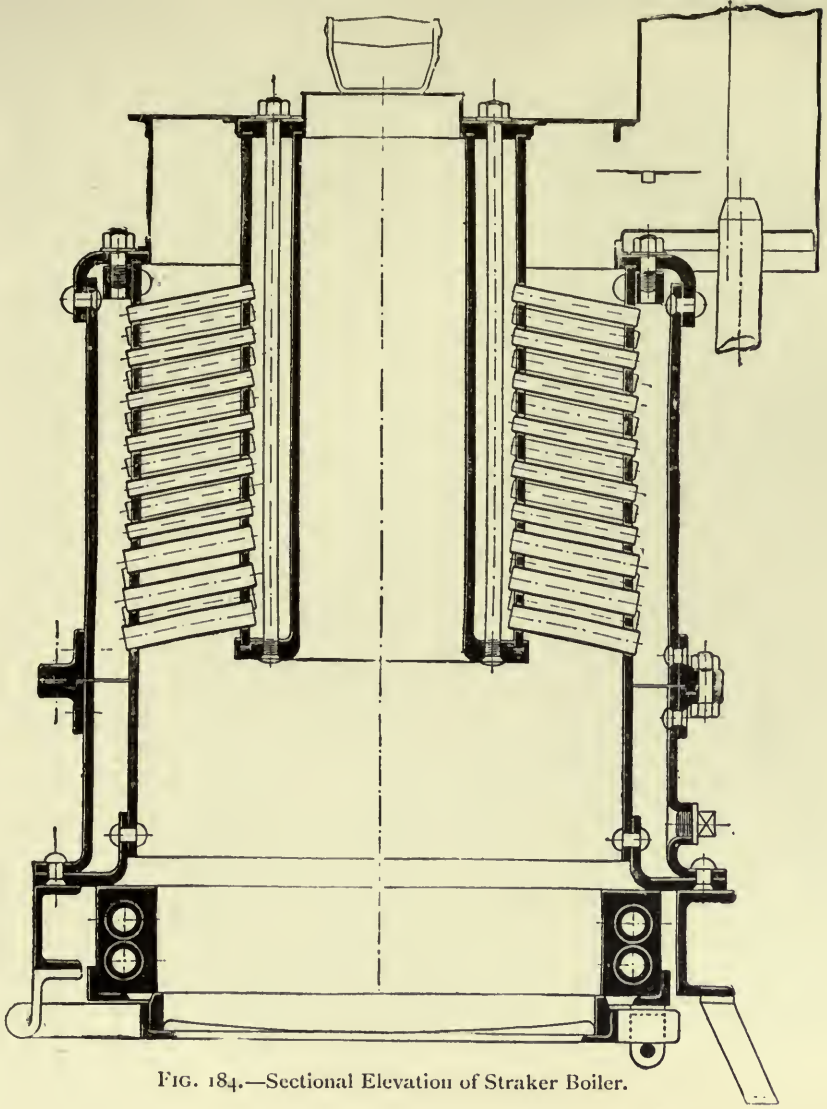


FIG. 184.—Sectional Elevation of Straker Boiler.

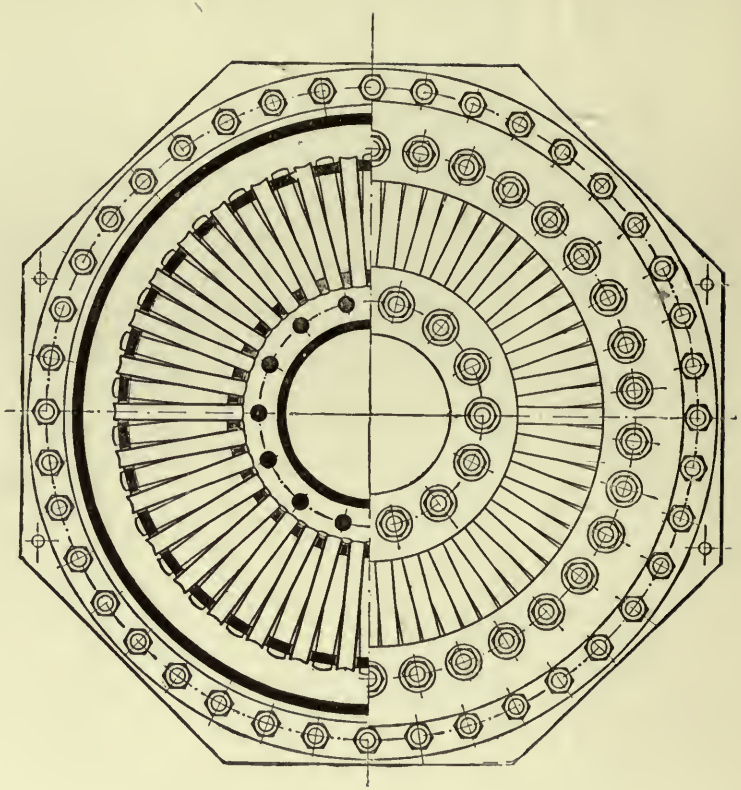


FIG. 185.—Sectional Plan of Straker Boiler.

only be broken at long intervals, when it may be necessary to replace any worn tubes. To clean flues the smoke box lid is removed, and a special tube brush is passed down diagonally between each row of tubes, and after going twice round the boiler the entire flue space has then been swept clean. The bottom tubes are cleaned from underneath, as per driver's instruction.

The possibility of a motor waggon getting into difficulties and tilting its boiler to a dangerous angle is a contingency which must be considered; with the locomotive or fire-tube type the fire must be drawn immediately, which deprives the vehicle of all power of helping itself out of difficulties. A boiler in which steam can safely be kept up, even when tilted at considerable angles, has therefore great advantages. Owing to the relatively low temperature in the upper portions of the Straker boiler, it is a matter of no great consequence where the water level is, within limits; therefore whether this falls through negligence or the boiler is tipped over to an angle no danger need be

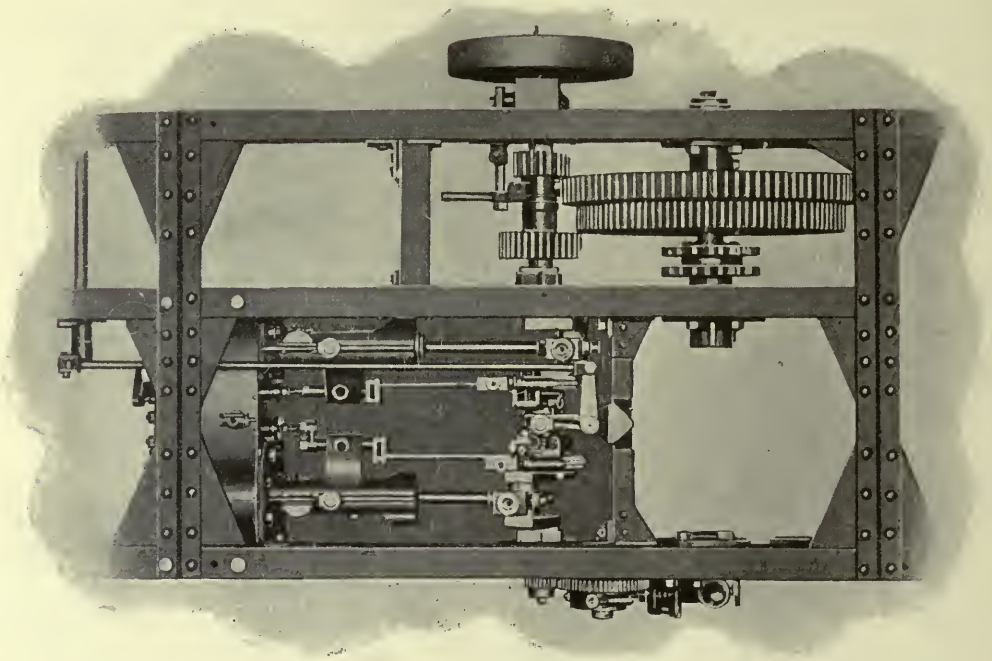


Fig. 186.—Plan of Straker Steam Engine.

apprehended. As will be seen by reference to Figs. 184 and 185, the only joints on the outer dome are kept well removed from the heat, and have one side exposed to the atmosphere.

Extracts from a report made by Mr. Stromeyer, of the Manchester Steam Users' Association, on the Straker boiler, which competed in the War Office trials in 1902 at Aldershot, are appended:—

"The water level in this boiler is below the upper row of tubes, so that the steam should be slightly superheated, or at least dried here. In addition, there is a small superheater round the fire-grate. With the large number of tubes in this boiler the danger of overheating the upper ones hardly need be apprehended.

"This boiler has two safety valves $\frac{5}{8}$-inch diameter, provided with wide lips. The sectional area is sufficient to relieve the steam generated. Observations were made during the trial which confirm this view, there being practically no accumulation of pressure when the valves were blowing."

PLATE VI.—STEAM ROAD TRACTION ENGINE.

The fires can be readily clinkered or entirely withdrawn, when necessary, by lowering one side of the grate.

An armoured coil is fitted round the fire box, through which the steam passes on its way to the high-pressure cylinder, and there becomes dried and superheated, thus eliminating all danger of priming.

The engine fitted to the 2-ton delivery van, being of high rotary speed and of relatively small dimensions, is of the closed in or splash type.

The 5- and 7-ton waggon engines shown in plan in Fig. 186 being of long stroke are of the open type, encased in a light dust-proof casing, made easily removable, thus laying the engine completely open for inspection without removing the load. The long stroke and comparatively slow speed ensure long life to both engine and gearing. The system of lubrication employed, whilst giving perfect results, reduces the oil consumption to a minimum, not more than 1 gallon per week being required for this purpose.

In dealing with heavy loads the best effect is secured by the slow-speed open type engine; those fitted to the 5- and 7-ton waggons are equally accessible both from above or below, whether the load is on or off. Following out the principle of accessibility, which is a characteristic of these waggons, the single eccentric reversing gear is fitted, thus admitting of linking up to requirements, and giving ample access to inside of engine for oiling, gland packing, etc., which does not exist with link motion.

The engines are of the compound horizontal type. The cylinders are lagged with asbestos and planished steel. The valves, which are of the piston type, work in cast-iron bushes, so that in the event of wear both valve and bush can be replaced, thus ensuring a perfect fit. All bearings are of the best gun-metal or phosphor bronze. Only the ordinary attention necessary with locomotives and other machines of a similar class is required for lubrication of the working parts.

The crank shaft is of mild steel, and the throws are set at right angles. It is provided with a balanced fly-wheel projecting on the outside of the frame, which forms a ready means of turning the engine by hand should occasion demand. The engine is simply disconnected, and can be run independently of the waggon. A double sliding pinion is provided on the squared end of the crank shaft, which gives two useful geared speeds. A cylinder lubricator is attached to the main steam pipe.

In order to transmit the power from the sprung portion of the waggon which carries the engine, boiler, etc., to the unsprung driving axle, a flexible drive is necessary to provide for the angular deflection which the back axle, owing to the working of the springs, is constantly assuming in relation to the rest of the waggon. The only two solutions are by the use of a flexible shaft and universal joint, or by a flexible drive. A third so-called solution is found in some of the rough traction engine types of waggons, in that no provision is made, the angular deflection being taken in the play of the teeth of the gearing. This is a direct invitation to wear and tear, and it may be dismissed.

The boiler is fed either by means of a direct acting, slow-speed plunger pump driven through gears off the engine crank shaft, or by means of the injector secured to the boiler shell. The capacity of either is more than sufficient to deal with the evaporative requirement of the boiler.

Fig. 187 is a plan of the standard 5-ton chassis with the engine cover removed, showing the small number of working parts and the general simplicity of the machinery.

THORNYCROFT STEAM ROAD WAGGON

The general features of the motive mechanism of the Thornycroft waggon are very clearly shown in the view (Fig. 188), which is made from a photograph of a vehicle with the body removed. It is taken looking from underneath the mechanism. In the 4-ton waggon the space available for the platform is 12 feet by 6 feet 6 inches. The engine,

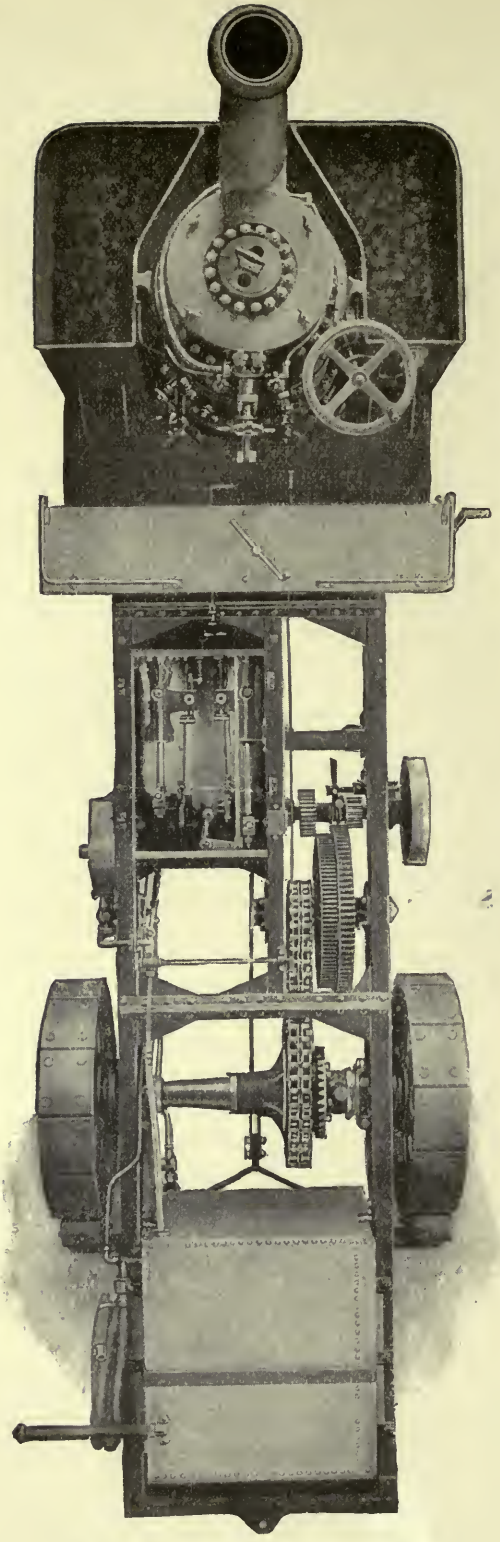


FIG. 187.—Plan of Chassis of Straker Steam Waggon.

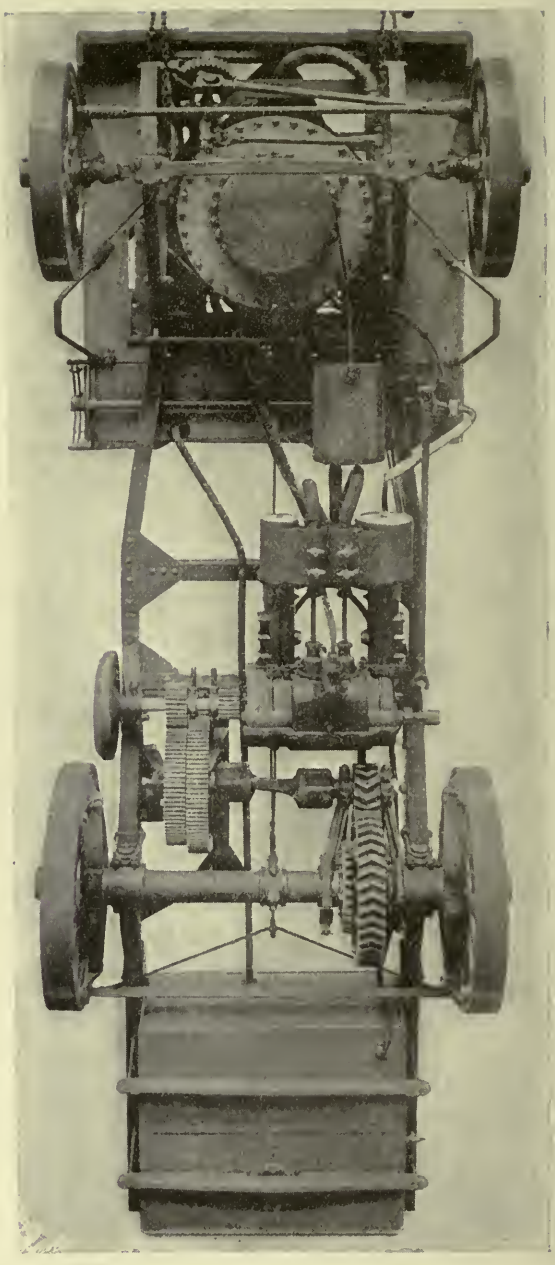


FIG. 188.—Under View of Thornycroft's Steam Waggon.

shown in Fig. 191, is of the horizontal compound reversing type, with cylinders 4-inch and 7-inch diameter by 5-inch stroke. It has a constant lead radial valve gear of special design, whereby any degree of linking up can be obtained. The cylinders and valve chambers are made of two iron castings. Sectional views of the valve chests are shown in Fig. 189. The transmission is of the chainless pattern, a pinion on the engine crank shaft meshing with a spur-wheel on the first-motion counter shaft. The latter is made in three distinct parts, the middle portion being connected with the first and third by enclosed universal couplings, so that the vertical motion of the bearing springs is taken up, and a continuous driving effort applied to the wheels irrespective of road surface and conditions of loading. One portion of this counter shaft carries two change-speed gears, and the other portion a double helical cast-steel pinion which engages a steel spur-wheel carried on the differential gear on the rear axle. The end of the shaft, on which is mounted the double helical pinion, is supported by a pair of triangular brackets from the rear axle. These brackets are prevented from turning round the rear axle by a radius rod hinged to the under frame of the vehicle, so as to permit full play of the bearing springs.

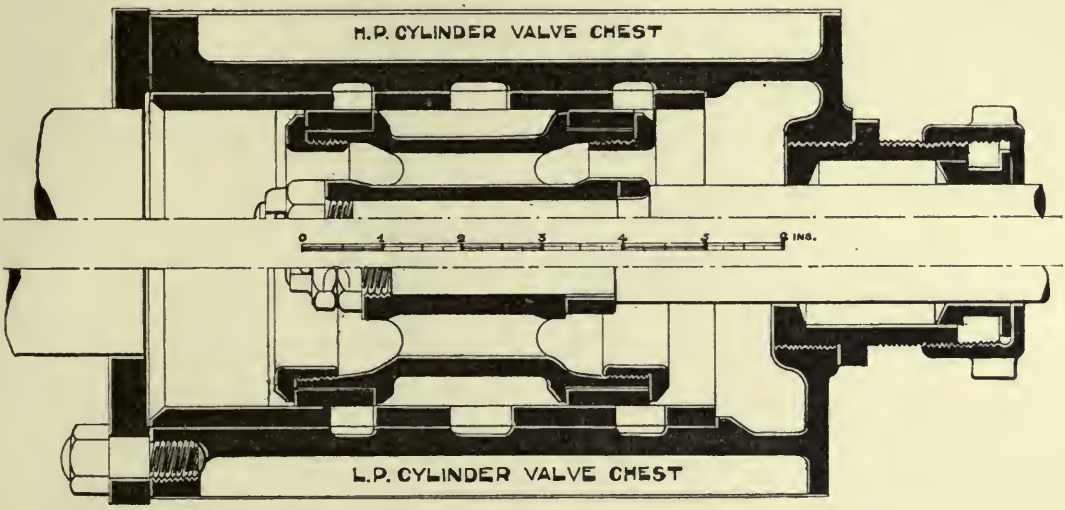


FIG. 189.—High-Pressure and Low-Pressure Cylinder Valve Chests of Thornycroft Engine.

The rear axle is carried in substantial axle boxes, and the road wheels are finally driven through plate springs attached to the felloes. It will be seen that the whole of the working parts of the engine are enclosed, the crank shaft and valve gear being contained in a cast-iron chamber, and the cross-heads in cast-iron sleeves bolted to the cylinders and crank chamber respectively. The cover of the crank chamber is of aluminium. The main frame of the waggon is of channel steel. The wheels are built up of oak spokes, ash felloes, metal naves, and stout steel weldless tyres—a form of construction which leaves little to be desired. The Ackerman system of steering is retained, the leading wheels being turned by a hand wheel operating through worm gearing. The boiler is of the Thornycroft central-fired water-tube pattern, using coke or coal as fuel. Fig. 190 is a sectional illustration of the smaller size. Greater steam space is allowed now than formerly, to prevent priming. The side clinkering door has been got rid of by the introduction of a vertically movable grate. The boiler comprises essentially two annular chambers connected by a series of 168 straight steel tubes $\frac{7}{8}$-inch expanded diamater.

The top vessel is built up of two separate rings of $\frac{5}{16}$-inch steel, riveted at their lower edges to an annular steel channel $\frac{1}{2}$-inch thick. The bottom vessel is composed of three plates, *i.e.* one tube plate and two rings. The tube plate is $\frac{5}{8}$ inch thick, and the rings $\frac{5}{16}$ inch.

The covers of both chambers are of steel, and are secured by bolts in the case of the top vessel and studs in the bottom. The tubes connecting the two vessels are 1 foot 11 inches long, and their mean inclination $1\frac{1}{16}$ inch to 1 foot. The heating surface in this smaller size of boiler is 77 square feet, the grate area 2.4 square feet, and the total weight $13\frac{3}{4}$ cwts.

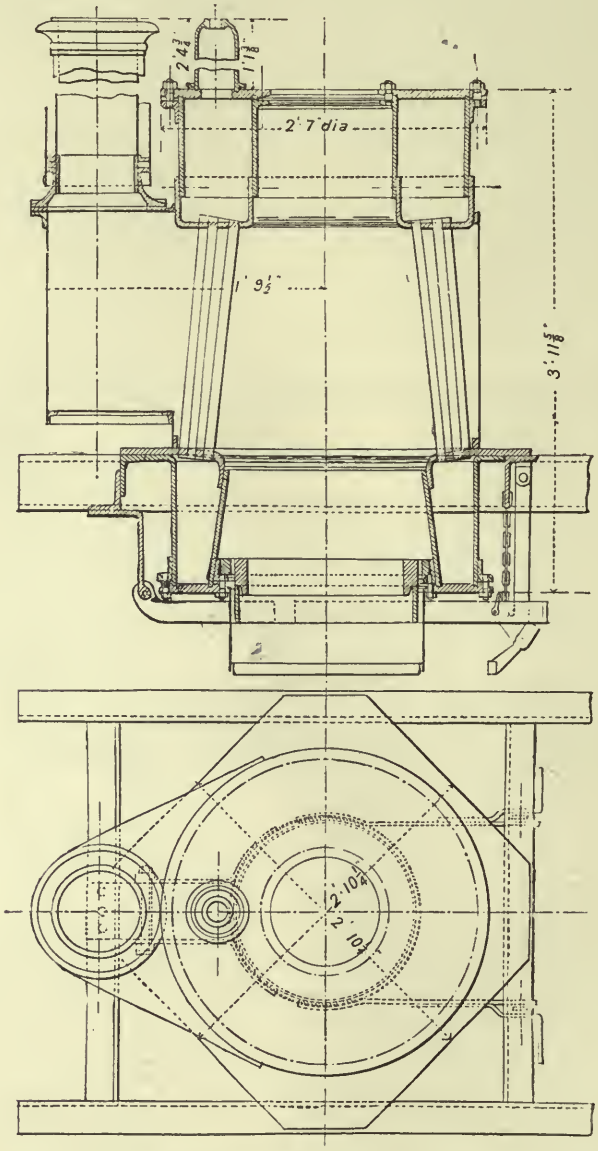


FIG. 190.—Sectional Elevation and Plan of Thornycroft Boiler.

The boilers are built for a working pressure of 200 lbs., and are tested up to 350 lbs. per square inch.

It is difficult to say in general how much it is going to cost per ton-mile to run waggons, as the conditions vary so greatly.

Therefore, to enable each for himself and his own particular case to gain some idea of the economy likely to be effected, we give here in detail the method of arriving at a figure in a specific instance.

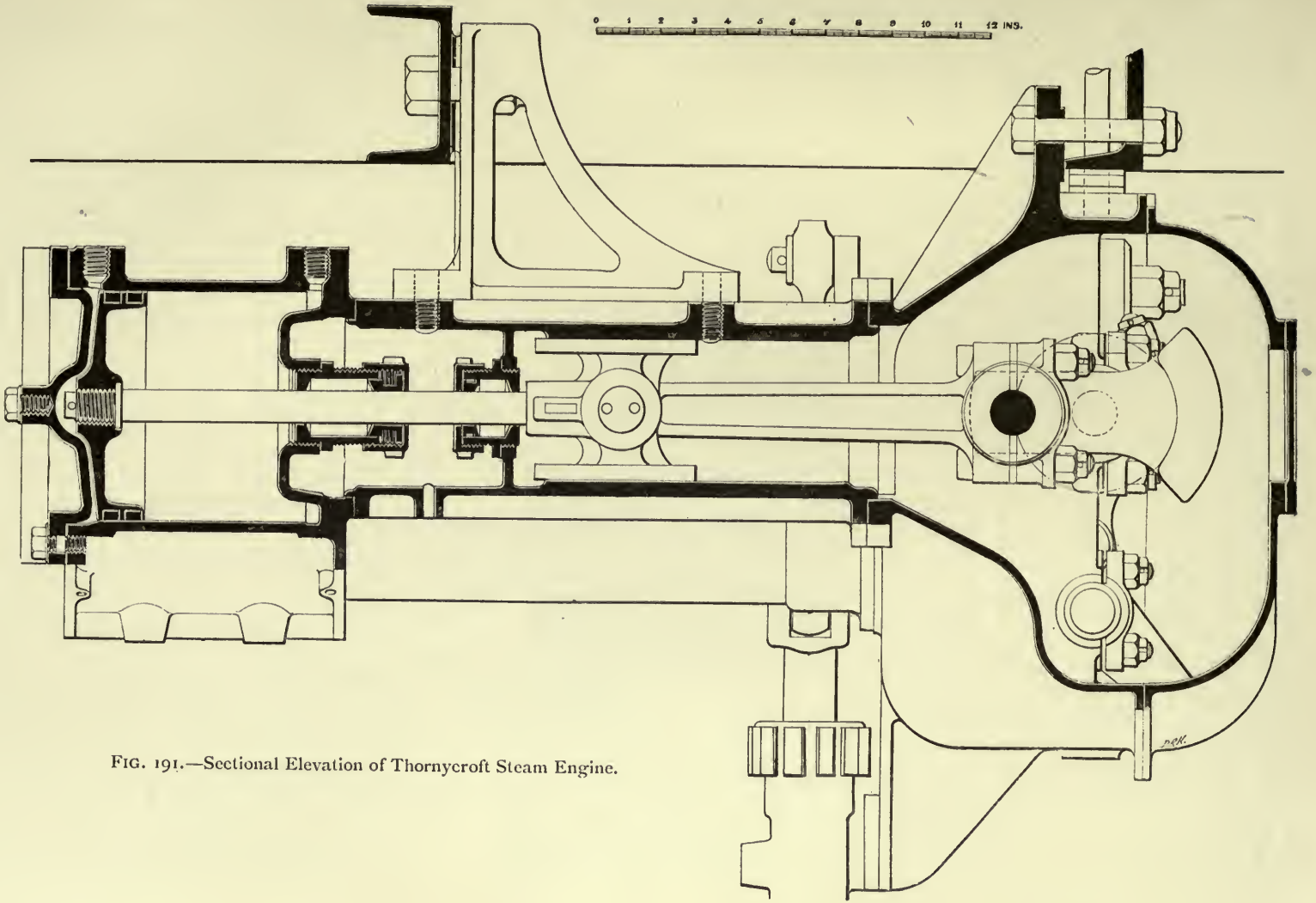


FIG. 191.—Sectional Elevation of Thornycroft Steam Engine.

Assume that goods have to be transported a distance of 18 miles, and that a steam waggon is contemplated, the cost of which is £707.

Interest on capital, 4 per cent.	£28	5	7
Depreciation, 10 per cent.	70	7	0
Repairs and maintenance	52	0	0
Driver @ 35/-	91	0	0
Coal, 50 tons	65	0	0
Oil and stores	10	0	0
	£316	12	7

Say that the total inclusive annual expense is £320.

The steam waggon will carry 3½ tons, and will make one round trip per day on five days a week, returning with, say, 1½ ton of empties. That is, 3½ tons carried 18 miles out and 1½ ton carried 18 miles home (5 tons carried 18 miles) each day, or a total of $5 \times 18 = 450$ net ton-miles per week. In a year, allowing a fortnight annually for general overhaul, this will amount to $50 \times 450 = 22{,}500$ net ton-miles, and the cost therefore of carrying 1 ton 1 mile will be $\frac{£320}{22{,}500} = 3.41$ pence.

About 35 to 40 miles may be regarded as the normal distance to be covered in an ordinary working day. If the service requires several short journeys with corresponding loading and unloading, of course a lesser aggregate distance will be covered in the same time.

Welsh coal, good gas coke, or oil may be used as fuel, and bunker capacity is provided sufficient for a full load run of 40 to 50 miles. When suitable fuel is used no smoke or steam is visible when running.

Plate V. shows in one view the top and under side of the Thornycroft steam waggon.

Plate VI. shows the Thornycroft steam waggon for transport service at the Indian Durbar.

THE WHITE STEAM AUTOCAR

As in the case of all steam cars, the feature which most invites inquiry is the boiler, or, as the constructors of this vehicle prefer to call it, the generator. It is carried on the frame beneath the front seat, and is enclosed in a thick jacket or shell of asbestos 1 inch thick, surrounded by a sheet-iron casing. Fig. 192 is from a photograph of one of these boilers with this asbestos shell removed, and, as will at once be seen, it is a water-tube boiler constructed of a series of coils of seamless steel tube, through which the water from the tank is pumped as it is required. The water passes first into the top coil, and is flashed into steam at a point about halfway through the entire length of the tube, receiving as it passes on through the remaining half a considerable amount of superheat, sufficient at all events to entirely preclude cylinder condensation, though not enough to burn the valves, etc. The entire amount of water in the tubes at any time is very small—certainly never exceeding a quart, so that by this fact, and the peculiar construction of the boiler itself, there is absolutely no possibility of explosion. The steel tube of which the coils are formed is of 0.53-inch diameter, and about ¼-inch bore, and in order that the water may not at once descend to the lower coils the end of each coil is bent upward to the top of the generator before making connection to the next lower coil. The lower end of the bottom coil is straight, and lies right across the burner. In this straight length of tube is placed the thermostat—a simple instrument which is provided to control the supply of fuel to the burner in accordance with the temperature of the steam.

The normal working pressure of this boiler is from 300 lbs. to 350 lbs. per square inch, and the steam influenced diaphragm controlling the bypass, which permits the water to flow either to the top coil of the steam generator or back to the tank, operates in the former sense at a pressure of 325 lbs. per square inch. As a matter of fact, the question of pressure needs no regard whatever when driving, as even so unlikely a thing as a failure of supply can do no harm to the boiler *per se*, the only result being the stoppage of the car.

The outer end of each coil is carried up to the top of the generator before connecting to the inner end of the next lower coil, to prevent the water from running down by gravity and displacing the steam in the lower coils. The straight pipe seen beyond the vaporiser conveys the steam from the lowest coil on its way to the engine. In this pipe is placed the thermostat, which actuates a valve controlling the fuel supply. In this manner the fire is regulated not by the pressure but by the temperature of the steam.

Now, with reference to the burner, which is also clearly seen beneath the generator in Fig. 192, the bottom plate of this burner is of sheet iron domed downwards, while the top plate is of cast iron, formed, as may be seen, with a number of concentric corrugations, with numerous cross saw-cuts through which the mixed air and vaporised oil passes for combustion.

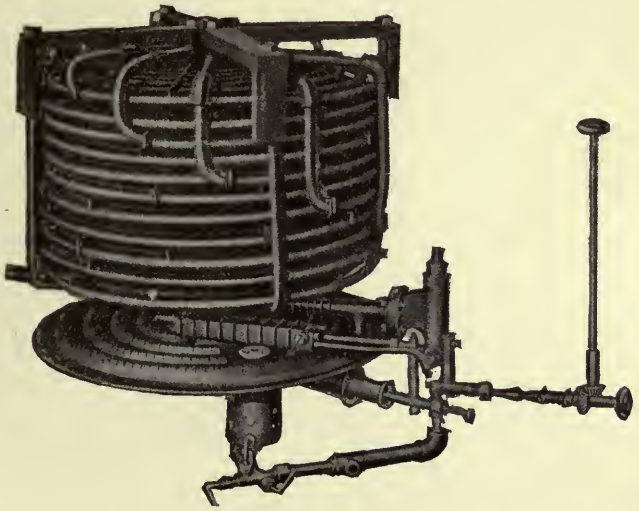


Fig. 192.—White Steam Generator.

The ribbed member seen lying partially across the burner is the vaporiser, and beneath this, and separate from the burner itself, is the pilot light, by which the apparatus for vaporising the liquid fuel receives its initial heat. This pilot light, once heated, always keeps alight, so that whenever the car is at rest the main burner can be turned completely off, the vaporiser being kept sufficiently hot by the pilot light to ensure an immediate start when desired.

As already indicated, the amount of fuel passing to the burner when the boiler is under steam is controlled entirely by the temperature of the superheated steam through the agency of the thermostat. To the uninitiated this sounds a very complicated instrument, but it is in reality a device of the simplest, though of the most ingenious description.

Referring again to Fig. 192, a length of straight pipe will be seen passing right across the centre of the burner, and projecting slightly beyond the bottom coil on the left-hand side of the picture. This is the lower end of the bottom coil, by which the superheated steam passes to the engine. In this straight length of pipe is placed the thermostat, which is nothing more or less than a length of copper rod, one end of which passes through the stopped end of the tube into the vertical cylindrical vessel seen on the right of the boiler. The expansion and contraction of this rod, acting upon one end of a bell crank lever within the cylindrical chamber, opens or closes a needle valve, through which the liquid fuel has to pass before it reaches the vaporiser. A change of 15° Fahr. in the heat of the superheated steam is sufficient to bring this apparatus into action. Thus the fuel supply is cut down before it reaches the vaporiser. The bypass valve in

the water supply is closed when the pressure falls, and then water passes to the coils, the temperature of the steam is reduced, the thermostat by its movement opens the fuel needle valve, and the fire is again raised. As a matter of fact, these functions, by the simple arrangement of the apparatus, go on quite automatically, and need absolutely no attention when driving.

AUTOCAR STEAM BOILER

A compactly built steam boiler for autocar work is shown in Fig. 193. It is of the fire tube type, and is central fired ; that is, the fuel is piled in from the top. The tubes are easily got at, and readily cleaned, as the route casing is removable. The fire-bars and ash pan are suspended beneath the boiler in such a way that they can be raised

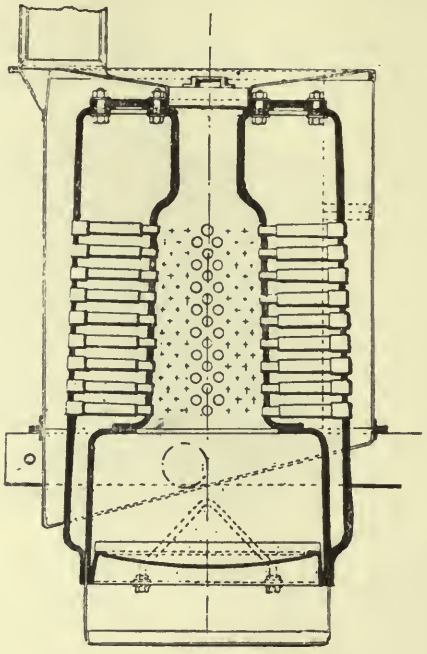


Fig. 193.—Steam Autocar Boiler.

or lowered by gearing fitted in front of the car. A feed-water heater and steam pump are fitted in connection with this boiler. The exhaust steam heats the feed water, and any condensed exhaust is returned to the feed-water tank. This type of boiler is fitted to the steam waggons made by Messrs. J. Robertson & Son, Fleetwood, and is designed for hauling a load of 5 tons.

CHAPTER VIII

PORTABLE OIL ENGINE AND ROAD ROLLER

In Plate VII. we have a portable engine designed for moving about on wheels and drawn by horses, also a road roller fitted with a similar engine. The roller is in use at Seine-et-Marne, in France, and is fitted by an engine of the Dudbridge Company make invented by Mr. T. G. Smith, a director of that company. The oil used is known in France as schiste; its specific gravity is 0.805. The trials prove economy in cost of fuel.

The engine is of 16 horse-power, is mounted on a wrought-iron framing carrying the driving gear, etc., much in the same way as in the case of the familiar steam roller. By means of a double-friction clutch the engine can be run in a forward or backward direction as may be required. All the various levers and other moving parts can be operated from the cab, which is covered by an awning. A compressed air reservoir is provided for starting purposes, this being charged by the engine when it is at work. Some few particulars as to the engine may be of interest. The general form is the same as that employed by the makers for their gas engines. Its approximate weight is about 70 cwts., and it runs at 180 revolutions per minute, the fly-wheel being 5 feet 4 inches in diameter and 7 inches wide. Its over-all dimensions are 10 feet long by 5 feet wide. Any of the well-known brands of petroleum, such as Russoline, Royal Daylight, etc., may be used. With an average oil the consumption is less than three-quarters of a pint per brake horse-power per hour, and that though lower consumption results than these have been obtained, yet the amount stated may be taken as an average consumption.

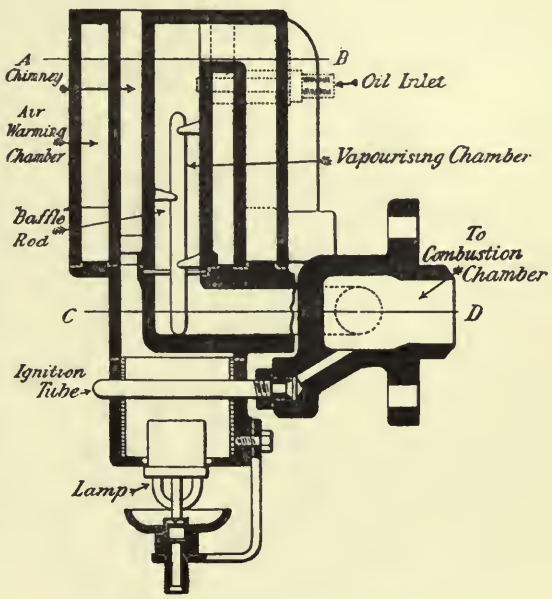


Fig. 194.—Dudbridge Vaporiser.

In order, of course, that these heavy oils may be used successfully, it is necessary to have a vaporiser of some form or other. That used in connection with the Dudbridge engine is shown in Figs. 194, 195, and 196, and the drawings will make its action readily understood. It is claimed that there is absolute freedom from deposit of carbon in the cylinder, and that the exhaust is perfectly clear. The vaporiser is of the type in which

a small portion of the air charge is heated to assist in vaporising the oil, the mixture then passing through the vapour valve into the combustion chamber of the engine cylinder, where it meets the main air charge entering through the air valve.

Looking at the various sectional drawings and Fig. 194, it will be seen that the central vaporising chamber is heated by a lamp which also heats the ignition tube.

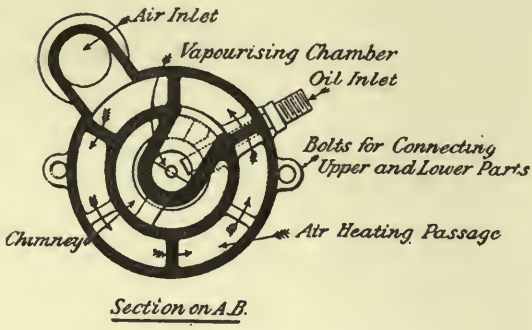


FIG. 195.—Dudbridge Vaporiser.

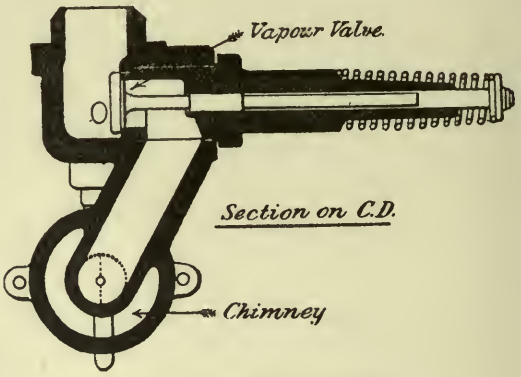


FIG. 196.—Dudbridge Vaporiser.

The chimney forms an annular space around this vaporising chamber (Fig. 195), and outside the chimney is another annular space in which the air is thoroughly heated before being brought into contact with the oil. It will be seen that the air-heating space is divided up into several passages by a number—in this instance six—of vertically placed radial divisions, reaching alternately to the top and to the bottom, so that the air must

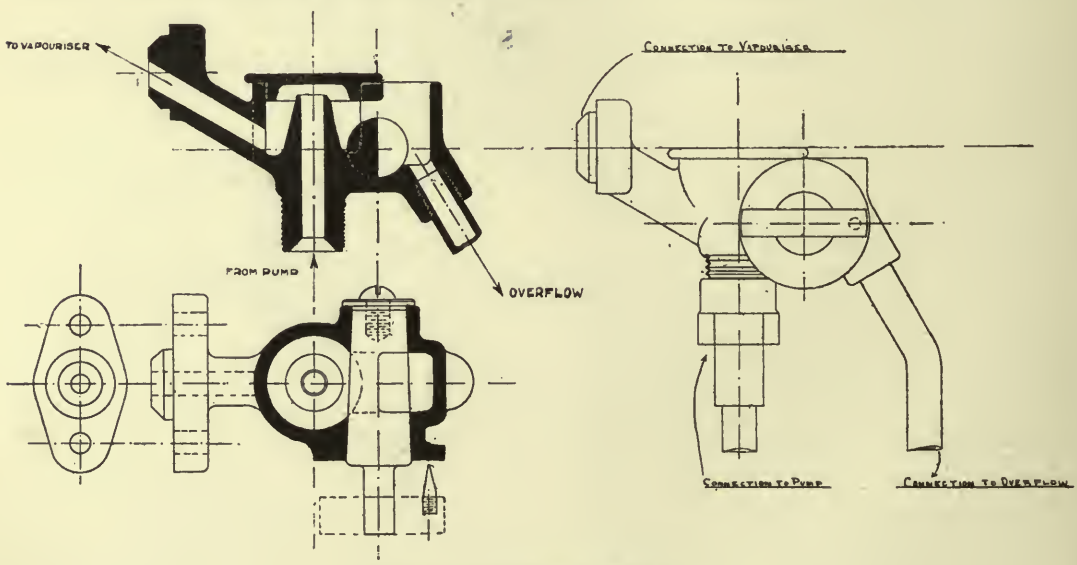


FIG. 197.—Oil Measuring Valve.

travel up and down the length of the space several times before being delivered into the vaporising chamber. The oil is supplied to the vaporiser in measured quantities by a gun-metal pump with steel valves, two suction and two delivery valves being provided with the object of assuring certainty of action. The oil is injected into the central chamber just below the inlet of the heated air, and the suction stroke of the engine draws it down past the baffles, which, as shown, are fixed to a central rod. These baffles are said to effectually break up the oil, and to ensure complete vaporisa-

tion. The whole of the upper part of the vaporiser may be removed by the unscrewing of two nuts.

The lamp used for heating the vaporiser and ignition tube is automatic, and is supplied with oil from a separate reservoir, requiring no further attention after being started. The oil supply may be renewed without stopping. The heat of the vaporiser is therefore not dependent upon the varying explosions in the cylinder, but is maintained at a constant temperature. The engine may afterwards be stopped as desired, and started again instantly, no reheating of the vaporiser being necessary.

The firm have recently introduced a new oil measuring valve, shown in Fig. 197, by means of which charges of uniform quantity are delivered to the vaporiser. The oil pump delivers a larger quantity of oil than is required into the measuring chamber, the excess escaping over the side of the plug cock to the overflow pipe back to the tank. By altering the angle of the plug cock the amount of oil remaining in the measurer may be varied to suit different loads on the engine.

CHAPTER IX

MISCELLANEOUS IMPROVEMENTS

A SIMPLE IMPROVEMENT ON PETROL ENGINES

Briefly stated, this improvement consists in providing a supplementary exhaust port in the cylinder of the engine in addition to the ordinary mechanically operated exhaust and inlet valves in a 4-stroke engine. This supplementary or auxiliary port is situated near the end of the out-stroke on the cylinder, so that the piston covers it and uncovers it at the end of its working stroke, and also at the end of the suction stroke. The port therefore performs two functions; first, at the end of the working stroke it allows of the instantaneous escape of the bulk of the exhaust gases, either directly into the atmosphere or through a silencer, so that the exhaust valve has only to deal with the residue of exhaust gases, and this residue is comparatively cool and of low pressure, and the valve remains in good order for a greatly lengthened period. The pressure of the exhaust gases at the end of the in-stroke is also reduced.

Secondly, at the end of the suction stroke the pressure of the fresh charge is always less than that of the atmosphere; hence when the port uncovers, air or inert exhaust gas enters and raises the pressure to that of the atmosphere, and this ensures higher compression and a greater total weight of fresh charge in the compression stroke.

The effects of this auxiliary exhaust and suction port are most noticeable at higher speeds, as it compensates for the lag of the exhaust and suction due to the valves and springs retardation action. The improvement can be applied to any 4-cycle engine without any additional mechanism. All that is required is to cast or drill the opening into the cylinder to form the port, and no valve is required on the port.

If a silencer is used on the engine it is applied to this auxiliary port, the exhaust valve pipe being then perfectly free.

Hitherto ports to be covered and uncovered by the piston at the end of the stroke have been common on 2-stroke engines, and without any exhaust valve. The invention here referred to consists in combining the port as an auxiliary to the exhaust and suction valves in a 4-stroke engine; for the purposes described above, the hottest portion of the exhaust escapes by the port, the remainder being swept out through the exhaust valve. There is also in the 4-stroke engine with the port as an auxiliary the effect at the end of the suction stroke.

This auxiliary port is a decided improvement on all 4-stroke engines, all of which suffer from the effects of the hot exhaust gases on the valves, and in all of them the suction stroke ends with a reduced pressure.

It is interesting to note previous claims to improvement in this same direction. The idea of an auxiliary relief valve is embodied in several patent specifications.

Not to go too far back, we may first notice specification No. 11,710 of 1897, shown in Fig. 198.

The engine is of the 4-stroke cycle type; a portion of the exhaust escapes at the end of the out-stroke through a valve a^3, which tends to prevent the cylinder from becoming unduly hot. The remainder of the exhaust is expelled by the piston through the valve E.

It will be observed in this combination that there is a third valve, that placed on the auxiliary port a^2. This valve would be subject to all the troubles of the ordinary exhaust valve, and prevents the port from acting on the suction stroke.

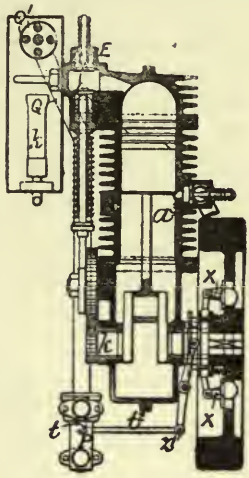


Fig. 198.—Auxiliary Exhaust Valve.

In specification No. 1426 of 1898 we have a further addition of an exhaust pump (Fig. 199). Towards the end of the out-stroke the exhaust valve *g* is first opened for the escape of the bulk of the burnt gases and is then closed, while the piston uncovers ports *j* leading to an exhausted chamber *k*, by which the residual products are withdrawn from the cylinder and a flushing charge of air and an explosive charge are drawn into it. The vaporiser *c* is joined to the cylinder by a neck *d*; the air valve *f* is opened by a cam *i*. In this improvement the hottest part of the exhaust is relieved by the valve, while the residue is drawn out by an exhauster; it applies to a 2-stroke engine only.

Next in rotation comes specification No. 13,796 of 1898, shown in Fig. 200.

This engine is designed for driving velocipedes, and works on a 4-stroke cycle. The cylinder and exhaust valve casing are surrounded with ribs *b*, *k*. The charge is admitted by a valve *l*, the supplementary air supply being controlled by a gridiron valve *y*. A supplementary exhaust port 22 is opened by the piston *c*. The exhaust valve *m* is operated by a cam 6 on a sleeve 8, which, besides rotating with the cross shaft, is slid to and fro by means of a stationary pin 10 engaging a cross groove in the sleeve, so that the cam misses the valve spindle every other revolution.

In this specification, as in No. 11,710 of 1897 just referred to, a valve is placed on the

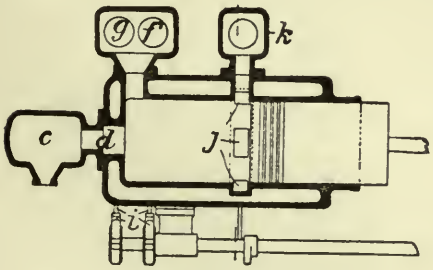


Fig. 199.—Auxiliary Exhaust Valve.

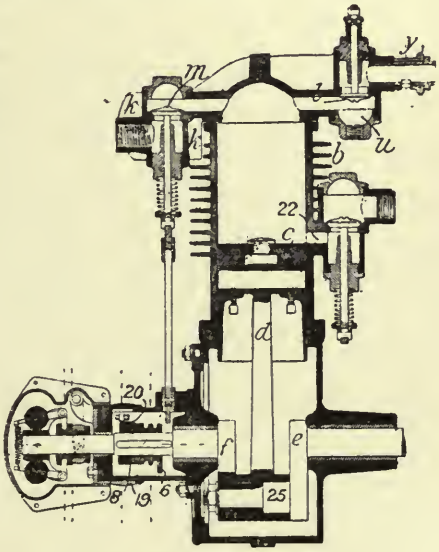


Fig. 200.—Auxiliary Exhaust Valve.

supplementary port, which has all the defects of the exhaust valve, and also prevents the port acting on the suction stroke.

The additional valve in all these designs is itself objectionable. In all inventions it is safe to assume that anything additional required is objectionable. Real improvements diminish the parts to accomplish the same effect, or else they accomplish better effects without increasing the parts. This simple rule is overlooked by many inventors,

forgetting that additional parts often introduce troubles of their own which far outweigh the advantages they seem to offer.

This may be illustrated by specification No. 8157 of 1900, wherein two additional valves are shown on the auxiliary port (Fig. 201).

The engine works on a 4-stroke cycle, the charge being arranged in layers in the cylinder, pure air next the piston, then products of combustion, and then the combustible charge. At the end of the power-stroke the exhaust valves 4 and 11 open, and the latter remains open until the end of the exhaust stroke. On the next out-stroke a charge is drawn from the carburetter 9, until the piston uncovers the port 3, when air is drawn in

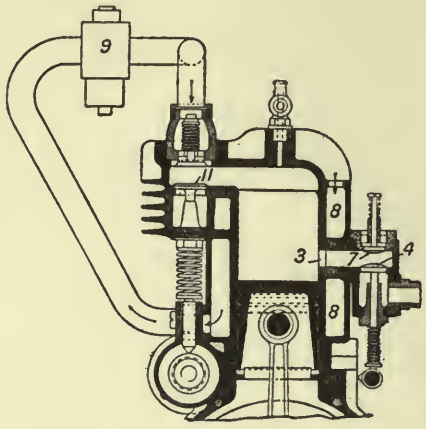


FIG. 201.—Auxiliary Exhaust Valve.

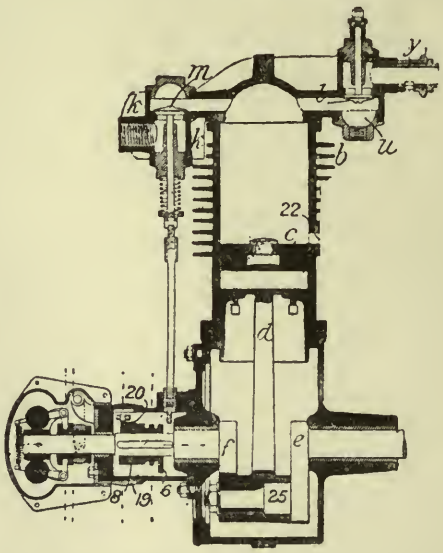


FIG. 202.—Auxiliary Valveless Exhaust Port.

behind the piston through the valve 7. The air drawn through the carburetter is heated in the cylinder jacket 8.

It is needless, perhaps, to point out that the two valves on the port are subject to the same deleterious effects as the two ordinary valves. Valve 7 would act only on the suction stroke if its spring were very weak, much weaker than the upper inlet valve spring, and it is exposed to the hottest exhaust gases.

In experimenting with an engine of this type the additional valves gave trouble. In fact, the engine worked as well when they were removed and the port plugged up. It was found, however, that it worked much better without the plug and without the valves, simply an opening into the atmosphere being left, as shown in Fig. 202 at *c*.

This small improvement is of some importance, hence the subject of internal combustion engines is again referred to in order to describe it and previous attempts in the same direction. The internal combustion engine is far from finality in design and improvement, and it is by small advances it is most likely to arrive at a more settled design.

The improvements to be obtained by an auxiliary port at the end of the stroke of the piston can only be realised on a perfectly free opening. Any additional valve at this port annuls all the benefits, and adds a worse than useless part to an engine.

VALVELESS INTERNAL COMBUSTION ENGINES

The introduction of furnace gases and producer gases as fuels for gas engines has stimulated the improvers of the larger gas engines. These gases are, however, liable to become foul from dust and tarry vapours and in time clog the valves, especially the inlet valves. A valveless engine is therefore of considerable interest; and as a thoroughly satisfactory design for a valveless engine is quite practicable and very desirable, the design of one shall now be given in detail by diagrams. We cannot just at present give an actual photograph of a valveless engine. At the usual rate of progress among engineers it will take from fifteen to twenty years to put them so far forward as a valveless engine implies. A valveless engine, however, will be a modern type sooner or later, and therefore finds a place in this work. It is quite as easily constructed as an engine with a multiplicity of valves and gearing, so dear to the average British engineer.

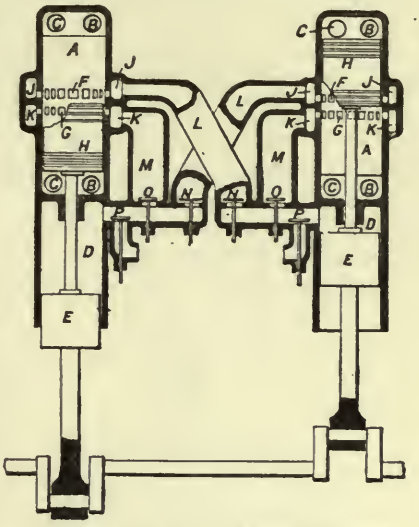


FIG. 203.—A recent Type of Engine.

It will be instructive to make an extract from a British Patent, No. 6646 of 1903 (Fig. 203)—not a very remote date. It is interesting as an engine which is certainly not valveless.

This invention relates particularly to methods of flushing the cylinders of gas engines with air for scavenging purposes. The engine is constructed with double-acting cylinders A, having admission and exhaust valves at both the back and front ends of the cylinders, B being the admission valves and C the exhaust valves. Instead of the ordinary cross-head and guide, the guide is constructed as a cylinder D, and the cross-head as a single-acting piston E. This arrangement forms an air pump. The cylinders A are constructed with two rings of ports F and G about their centres. The length of the pistons H is equal to or greater than the length of the stroke, and they are so arranged that as each piston moves to and fro it uncovers the ring of ports G to the lower end of the cylinder as the crank is passing the back dead centre, and opens the ring of ports F to the upper end of the cylinder as the crank is passing the forward dead centre. Each ring of ports has an annular belt J, K, connected by an air passage L, M, through a valve N, O, to the air pump. Each of these valves is mechanically operated once every two revolutions, it being arranged that the pump discharges its air alternately during one revolution into the passage leading to one ring of ports, and during the next revolution into the other passage, the passages acting as reservoirs in which the air is brought to a pressure of a few pounds. On the forward stroke of every revolution the air pump draws in air through valve P. In the operation of the engine, as the piston approaches the end of its stroke, the exhaust

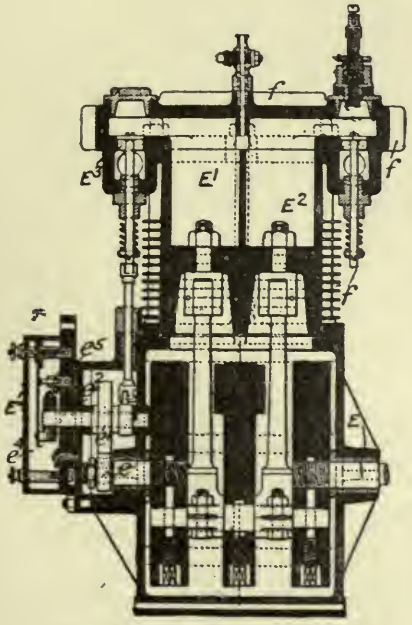


FIG. 204.—Two-Cylinder Engine.

valve C is opened, and the pressure in the cylinder falls ; the piston, continuing its motion, uncovers the ring of ports F or G. Air rushes in and scavenges the cylinder as the crank is passing the dead centre.

It will also be interesting to refer back to two engines with double pistons and cylinders side by side, one No. 14,649 of 1897 and one No. 8972 of 1900 (Fig. 204).

In the first one the engine is preferably made with two cylinders E^1, E^2, having projecting fins *f* to increase the cooling surface. Both pistons are connected to one crank pin, connecting discs secured on the shaft E. A counter shaft e^2, driven at half speed by cog-wheels e^1, *e*, carries a cam which opens the exhaust valve E^3 once in every alternate revolution of the shaft E. A notched disc e^5 on the shaft e^2 actuates a contact spring e^4 carried in an insulating box E^4, thereby actuating the accumulator, etc., and causing a spark to pass the igniting match e^6 and fire the charge. The box E^4 is so secured that the moment of ignition, and thereby the speed of the engine, may be adjusted by altering the relative positions of the disc e^5 and spring e^4. The motor is started by rotating the pedals with the feet.

In the second specification two or more cylinders 15, working on the 4-stroke cycle and with pistons 32 connected to parallel cranks 9 on the same shaft 8, have a common combustion chamber 18, and centrally placed admission and exhaust valves 21, 23, and electric igniter 1, which produces sparks when the circuit is completed by the apparatus shown in Fig. 205. Each cylinder is separate, and is surrounded by cooling ribs 17, 19. The engine is suitable for motor cars and boats.

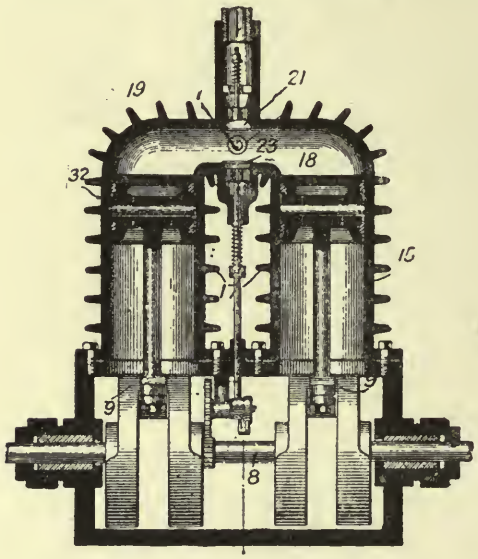


FIG. 205.—Two-Cylinder Engine.

If, however, we go back to 1892 we find Oechelhaeuser with two pistons and two cylinders end to end instead of side by side, and with ports on the cylinders through which the exhaust escapes when uncovered by one piston while the fresh charge enters by ports uncovered by the other piston, so that the engine itself is valveless ; but the fresh charge requires to be pumped into the inlet ports by a pump worked by the engine. This charging pump is common to many engines, and may be seen in the Clerk engine of 1883 and in Patent 3663 of 1903, the Körting engine, and others.

The pump has valves and comes between the gas producer and engine, so that the claim for a valveless engine is spurious in engines with a charging pump. The valves are all there, only they are shifted from the engine to the pump.

Engines in which the exhaust gas were drawn out by suction, and the fresh charge following the partial vacuum thereby formed were examined, one dating as far back as 1884 was found, but it is impracticable, and in all of them, up to the present date, valves are used, some using both inlet and exhaust valves, others inlet valves only.

It was found, however, that the problem could be satisfactorily solved by combining a suction or gas exhauster on the exhaust ports of an engine of Oechelhaeuser type, instead of a pump forcing in the charge. The Oechelhaeuser combination consists of two sets of ports, inlet and outlet, opened and shut by pistons, with a force pump to drive in the fresh charge through the uncovered inlets, while the fresh charge sweeps the exhaust out of the uncovered outlet (exactly as the exhaust was made in Clerk's prior engine). The new element in Oechelhaeuser being the admission of the charge through the uncovered ports instead of through a valve, but the charge has to first pass

through a pump and its valves, both in Clerk and Oechelhaeuser engines. The object of the present improvements is to abolish this pressure pump and its valves, which come between the producer and engine in Clerk and Oechelhaeuser engines.

This is accomplished by the combination of uncovered ports, inlet and outlet, one or two pistons with a continuous gas exhauster, a fan or ejector on the exhaust, so that the exhaust is drawn out and the fresh charge drawn in without passing through valves or pumps—a consummation which cannot be achieved by any other combination.

The drawing in of the charge, after the exhaust, drawn out by a gas exhauster, is in itself not new in engines, but this has hitherto not been done without valves on the inlet, and sometimes has been done with both inlet and outlet valves on an engine. It is the combination of this gas exhauster with inlet ports and outlet ports, opened and shut by the piston or pistons at the end of the stroke, which enables this new engine to work without valves or pumps, and this is the combination which is claimed in the invention.

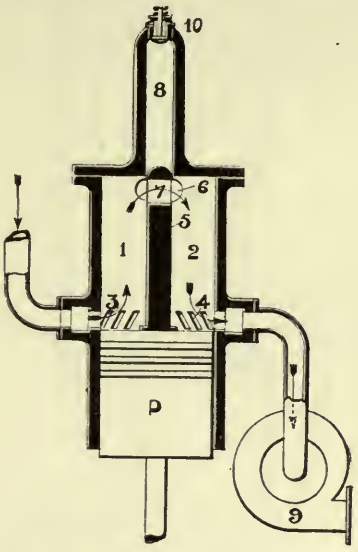


FIG. 206.—Valveless Single Cylinder Engine.

The invention is applicable to many other engines. It can be applied to a simple single-acting single-cylinder engine, as in Fig. 206, in which the cylinder is divided into two chambers by a partition carried on the piston head. The inlet ports are on one side, the outlet ports on the other side of the partition, and the outlet is shown attached to a fan

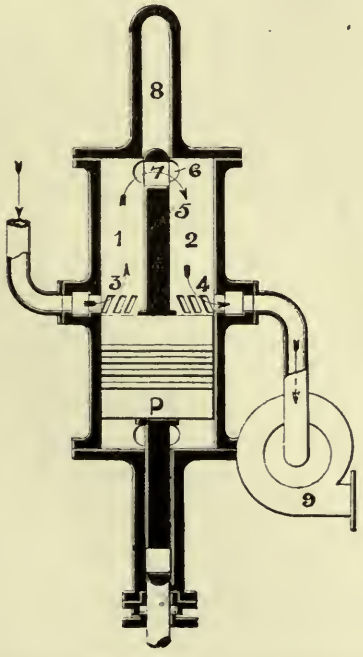


FIG. 207.—Valveless Single Cylinder Engine.

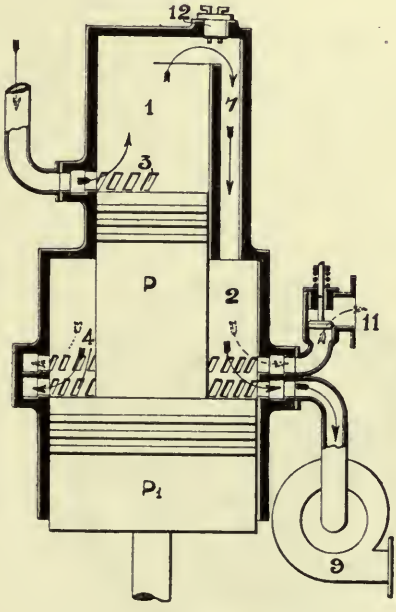


FIG. 208.—Valveless Engine.

exhauster 9, drawing out the exhaust and drawing in the fresh charges through the ports 3 and 4 uncovered by the piston. Fig. 207 shows this engine made double

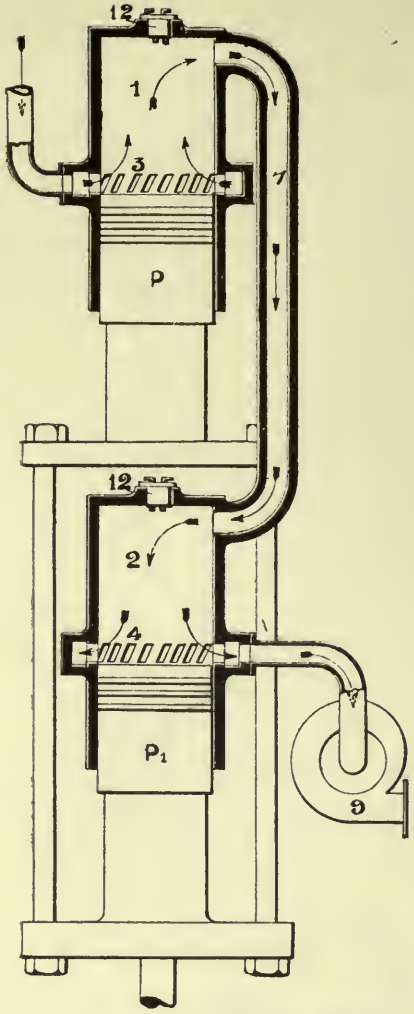


FIG. 209.—Valveless Tandem Engine.

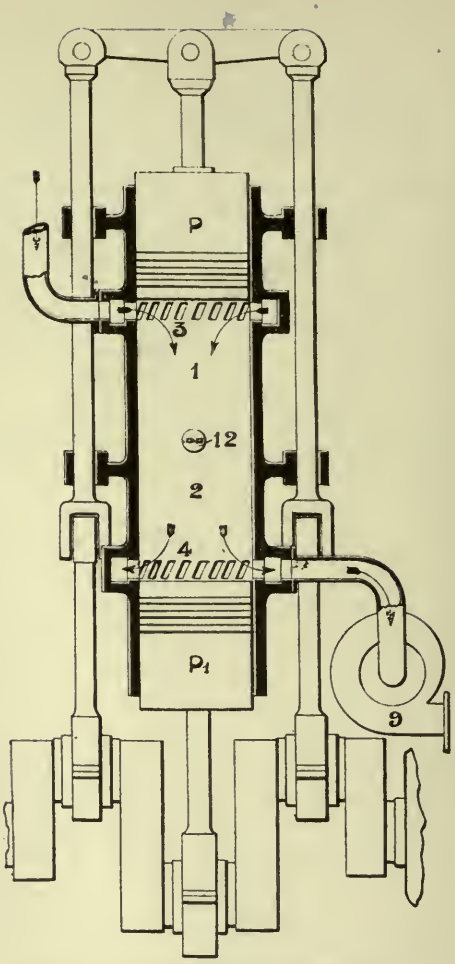


FIG. 210.—Valveless Two-Piston Engine.

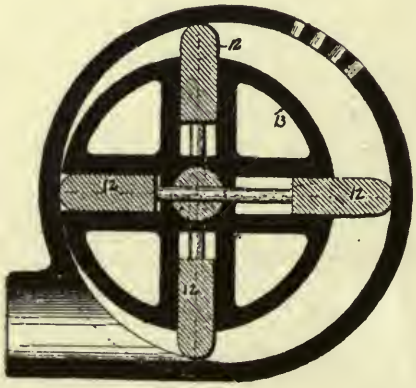


FIG. 211.—Crowel Exhauster.

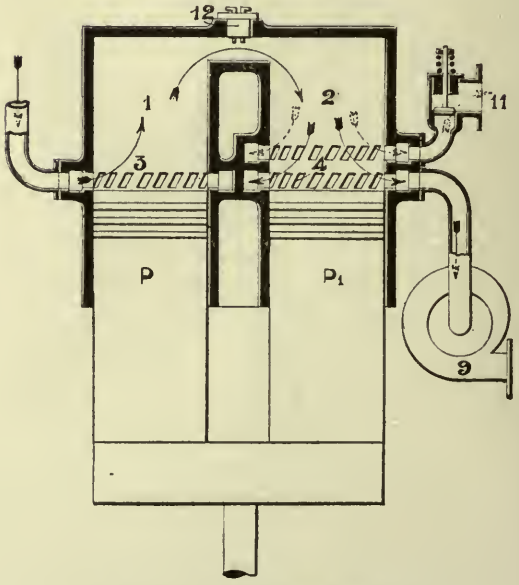


FIG. 212.—Valveless Engine.

acting, the piston uncovering the ports 3 and 4 at both the up and down end of the strokes.

Fig. 208 shows the invention applied to 2-piston engines having two cylinders in tandem. In the figure shown is a relief valve at 11 on the exhaust port. This has for its object the reduction of the pressure of the exhaust gas to that of the atmosphere before the ports to the gas exhauster open, and so that a smaller exhauster may suffice.

Fig. 209 is another type of tandem engine according to this invention.

Fig. 212 shows another type with two cylinders side by side and two pistons, the charge being compressed and fired in a combustion chamber between the two pistons.

Fig. 210 shows the invention as applied to the Oechelhaeuser type of engine.

In the type of engine shown in Fig. 210 the compression may be very high, as all the charge can be compressed into the passage communicating with the two cylinders, and this passage can be easily well cooled by a cold water jacket to prevent preignition.

A fan is shown as the gas exhauster in all the diagrams, but only as a type of exhauster in practice. A steam ejector or other gas exhausters may be used.

The fan shown is only diagrammatic. A positive exhaust pump, such as that of Crowel, shown in Fig. 211, would be used in practice, and the exhaust gases cooled in a cooler with cold circulating water.

The design for a 500 horse-power valveless engine is shown in Fig. 213 in end view and front elevation partly in section. It is of the design shown previously in diagram 212.

It has four pairs of cylinders on four cranks, and is properly valveless, with the exception of the relief valve on the exhaust. This valve is added solely to reduce the pressure and volume of the exhaust gases to be dealt with by the cooler and gas exhauster.

In large engines the cooler may be a steam boiler, in which case the heat of the exhaust gases is utilised instead of being wasted in a cooler.

The engine is designed specially for marine purposes, and for using producer gases as the fuel.

All the world is now alive to the internal combustion engine's importance as a prime mover, not only on land vehicles but on ships also; still, British engineers lag a long way behind the rest of the world; and so do Americans. It is a common mistake to suppose Americans are alive to novel inventions. They are more speculative than British engineers, but like them they excel most in pushing commercially something which has grown beyond its infancy. Anything old and well-matured suits them best. Quite recently some British firms have been aroused by the success of large internal combustion engines on the Continent of Europe, and now we find them introducing, as something new and progressive, types of engines patented and worked on the Continent from twelve to fifteen years ago.

Inventors for fifteen years or more have been urging in vain advantages of the suction gas producer and improved gas engines, and only now in 1904 do we find a few engineering firms commencing to manufacture suction gas producers and large power gas producers.

However, we are moving in the procession of progress, however far in the rear, as a few important observations made in a discussion on Power Station Design at the Institute of Electrical Engineers will show. In this discussion, April 1904—

Mr. A. H. Dykes considered that the gas engine had not received fair treatment by the authors. Although the future of the large station probably rests with the steam turbine, yet the diminished fuel costs and saving by residuals in gas engines cannot be overlooked. The labour cost over the whole of a gas station would be much less, and the repairs not necessarily higher than in the case of a steam station. He was putting down a gas engine plant, consisting of four 250 horse-power engines, which, on cheap fuel, were guaranteed to run on 1.63 lbs. per kilowatt-hour. The capital cost of

gas plant had been much reduced during the last few years—the cost of the above gas engines and generators was £13 per kilowatt, and, including the producers, £18 per

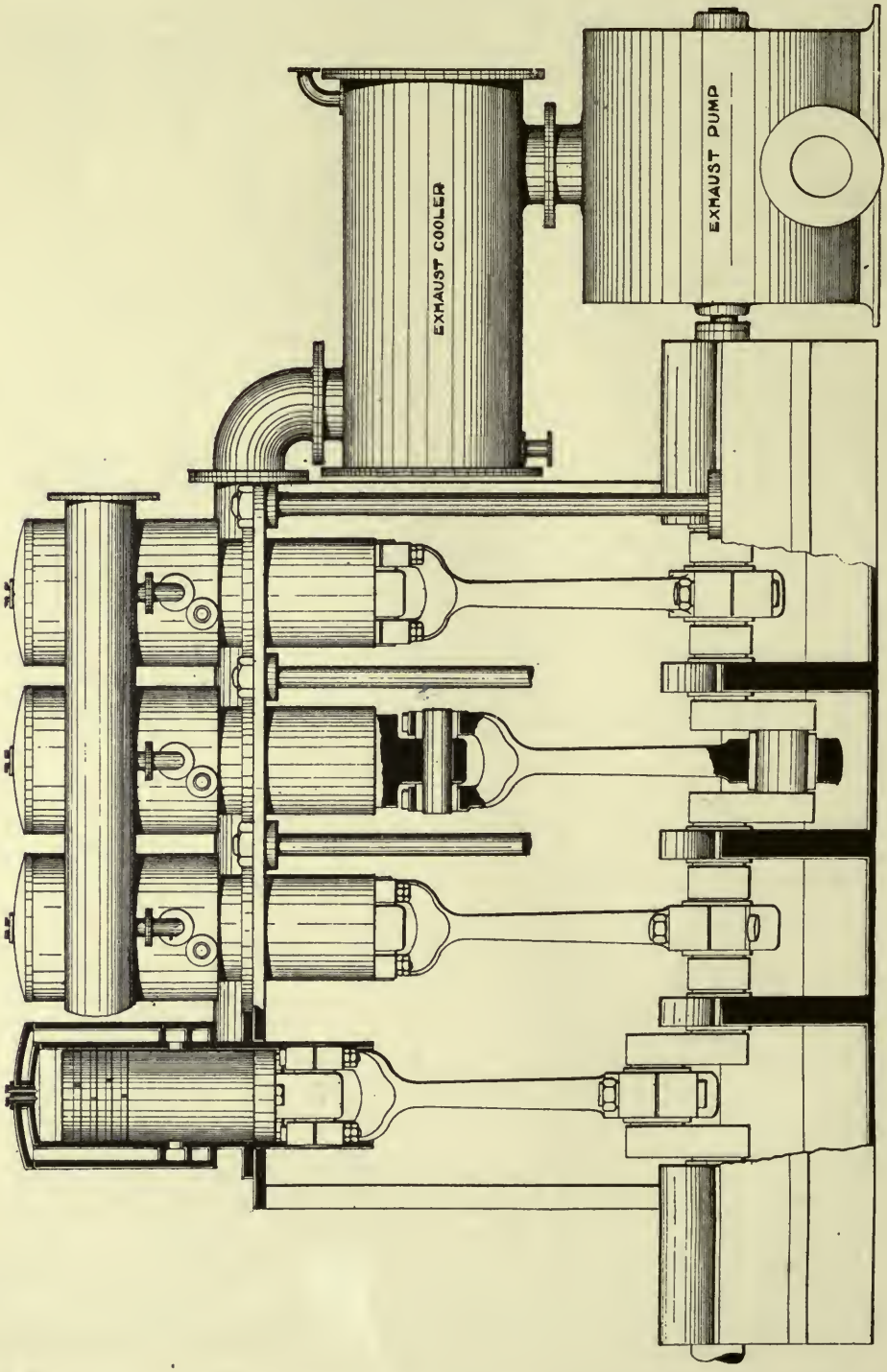


FIG. 213.—Front Elevation of Rankin Kennedy's Eight-Cylinder Valveless Marine Gas Engine.

kilowatt. These figures for small plants compare very favourably with steam plant. The cost of buildings is very much reduced, and the exhaust gases can be utilised for

water heating. It is also possible to provide overload capacity in gas engines if required.

Col. Crompton considered that the authors had barely referred to the use of gas engines for generating purposes. "The small gas engine station up to 1000 horse-power was cheaper than the steam station, but for large powers steam was still unrivalled. He thought that the turbine principle would be eventually applied to internal combustion work. In his opinion engineers had been blind to the advantages of water-tube boilers, correct boiler setting, superheated steam, and perhaps thermal storage; the latter would greatly reduce boiler capacity and capital cost."

Mr. E. K. Scott criticised the arrangement of turbine plant. The comparatively large space occupied by the boilers was sufficient, in his opinion, to turn the scale in favour of gas generating plant; and in regard to the latter, the gas turbine was, he thought, the coming thing.

From these opinions it can be gathered that engineers are at last alive to the question of gas *versus* steam, and that they anticipate the arrival of the gas turbine.

Gas, however, has already established itself as a formidable rival to steam power both for large and small powers. The movement in Great Britain some few years ago in favour of distributing energy from steam power stations by means of electricity was as usual belated. Such a scheme had some chance of commercial success twenty years ago before the gas producer and engine had been developed. But nowadays the power user can produce gas power which he can distribute in his factory by electricity or otherwise at a cost per unit much below that at which any steam generating station can produce it; not to speak of the cost of distribution and transmission.

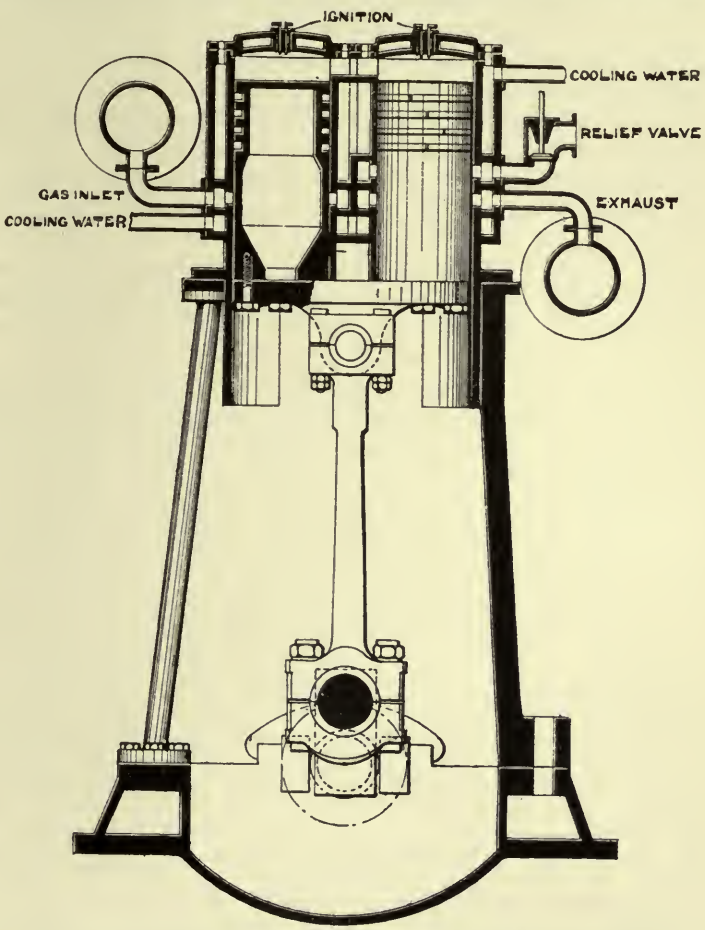


FIG. 214.—End Elevation of Rankin Kennedy's Eight-Cylinder Valveless Engine.

This waiting policy, waiting until a new invention is developed and matured before taking it up is believed in, as good policy for engineers and capitalists, but it has its drawbacks, the chief one being that by the time they consider it safe to go into the business the new inventions are ten to fifteen years old, and if not already improved upon are to be superseded immediately.

In the face of present-day internal combustion engines and power gas producers

there never was a more foolish proposal than that for the distribution and transmission of power in bulk from steam power stations by electricity.

Even with gas power stations it would be a risky business, for the great cost of distribution would add so much to the price of the unit delivered that the power user would do better with his own gas plant.

The steam turbine after six decades has been at last recognised as an improvement on the piston and cylinder engine to which engineers have so fondly clung for a century, and to which some of them will hold on to for another century. By the time the steam turbine is manufactured as a standard article—that is, when it is about twenty to thirty years older—the gas turbine will have come out as a far superior prime mover, to the great astonishment of the makers of the new steam turbine thirty years old.

In this work we have already had descriptions of pioneer gas turbines. These by no means represent what has been accomplished. The most recent achievements are necessarily not available for publication, but before the conclusion of the last volume of this work I believe the practicable gas turbine will figure largely in the engineering world.

Previously it has been pointed out in these volumes that the gas turbine would differ largely from the steam turbine, the two working fluids differing radically in their relation to heat. All inventors who have made their attempts by copying steam turbines have failed, and were bound to fail of success. One of the oldest prime movers on earth is a gas turbine, that is the windmill. The wind is produced by heat applied to the air at one place, and cold applied at another place. The expansion and contraction of the air sets up a current of great velocity, and this current of air drives the windmill.

In a hurricane the pressure of the blast may exceed 0.27 lbs. per square inch, due to a wind velocity of 145 feet per second. If this great velocity and pressure could be kept up very powerful windmills could be set up anywhere. Ordinary windmills are made for velocities of about 35 feet per second, and pressures of about 3 to 4 lbs. per square foot.

The rule to find horse-power of windmills is—

$$\text{E.H.P.} = 000{,}0002 \times D^2V^2,$$

where D is diameter of sail and V velocity of air in miles per hour.

Another rule, where A = area of wheel blades, is horse-power $= \frac{AV^2}{1{,}080{,}000}$.

It is from the windmill that the successful gas turbine will be developed.

AIR AS THE WORKING FLUID IN TURBINES

In all internal combustion engines air is the working fluid mixed with products of combustion; external combustion engines we have described in which pure air is used. And as the turbine type of motor offers many advantages to the use of air heated either internally or externally, an examination of the conditions of working will be of some interest.

There are many obvious difficulties in practice in using hot compressed air as the working fluid with a cylinder and piston engine. The first great difficulty is to apply the heat when external combustion is employed. Air allows heat to pass through it without itself becoming heated; it is heated only by contact with hot surfaces, and by convection, so that if any considerable volume of air is to be heated it must be passed over a large area of hot surface, and time must be allowed for convection to take place.

The air heaters subjected to high temperature gradually burnt out, and even with a bright red heat on the heaters the air seldom attained a temperature of more than 1000° Fahr. If the air could have been heated in a separate large heater, in which a large bulk of air could be retained long enough to thoroughly heat it, the difference of temperature

between the furnace and the air sides of the heater would have been much less, but heating in separate vessels entails the use of valves to pass the hot air, and no valves could be made to stand that exposure for very long.

Then again, the range of temperature in the fluid in the working cylinder is small. Air cannot be expanded below atmospheric pressure in an air engine cylinder; hence a great amount of heat is rejected with the exhaust.

Then there is the waste of heat by conduction through the cylinder walls.

The cylinder and piston engines working with hot air on any known cycle—Stirling or Joule, or Ericssons—must of necessity be bulky, and the hot air consequently exposed to very large cooling surfaces. Again, the effective working pressures are low compared with steam engine pressures, and with the maximum pressure in the engine itself. Thus in the Buckett engine (see page 15, Volume II.) in one case the initial pressure was 28 lbs. and the mean pressure 18.5 lbs., showing a very small range of expansion, the air being admitted for half the stroke at a temperature of 900° Fahr. Cut off and expanded to twice the volume, and discharged about 500° temperature, 20 horse-power was obtained on the brake.

It can be shown that the efficiency of such an engine depends upon the temperature of the air before compression and the temperature after compression, both absolute scale, and is independent of the maximum temperature. Thus

$$1 - \frac{T_a}{T_1} = E.$$

T_a = Atmosphere temperature.
T_1 = Temperature of air due to compression.
E = Efficiency, ideal or theoretical.

For example, if it takes in air at 60° and by compressing it to 29 lbs. per square inch pressure the temperature is raised to 255°—

$$T_a = 60+461 = 521$$
$$T_1 = 250+461 = 711$$

$$\text{Hence— } E = 1 - \frac{521}{711} = 0.268.$$

The actual efficiency was only about 0.1.

In this type of engine working at constant pressure the effect of higher temperature does not increase efficiency, but increases the power of the engine available for work.

If no heat is given to the compressed air no work would be available; the more heat given to the air after compression, the greater is the difference between the pump diagram and motor diagram, and therefore the greater the effective brake horse-power. But for the reasons given, and for another reason in addition, namely, the necessity for internal combustion to heat the compressed air, and the consequent mixing of the air with the furnace gases, the cylinder and piston hot air engine working on the Joule cycle fails. Internal combustion heating was necessary in a piston and cylinder engine, for the reason that a pumpful of air had to be heated and disposed of in the motor before the succeeding pumpful came in. If the engine made 100 revolutions a minute, there was therefore only 0.3 seconds in which to heat the air from 60° to 1000°. The quantity of air could not be heated in that time by the slow method of external combustion, hence the internal combustion method was at first and has ever since been adopted in cylinder engines.

This Joule cycle of working a heat engine is the one on which Ferranti's turbine, described in Volume I. page 190, and in a turbine diagram, Volume II. page 41, are operated. But although it is necessary in a cylinder and piston engine to adopt a rapid method of heating the fluid, *i.e.* by explosion in the gas and oil engines, and by furnace combustion in the hot air engine, and mixing the air with hot furnace gases, it has for long been clear to the author that there was no necessity for a rapid heating of the fluid for working turbines. In fact, it is quite clear that internal heating in a furnace had almost intolerable difficulties, the chief being the almost insuperable difficulty of

regulating the combustion, and the consequent temperatures, especially when solid fuel is used. Acting on these convictions, experiments confirmed them, and in a hot-air turbine, working on the Joule cycle, it was found quite easy to get the necessary temperatures by slow heating by external combustion. And by causing the cold air to enter by the cooler end of the air heater, and leave by the hotter end, it is possible to impart from 11,000 to 12,000 ⊖ of heat per lb. of coal consumed, to the air, and to transmit 6000 to 7000 ⊕ per square foot of heating surface.

Taking the heating value of the coal as 14,000 ⊖, the efficiency of the heater is at the lower value $\frac{11000}{14000}$,—0.8 nearly. Very few steam boilers can equal that result, and the heat imparted to air can be used about six times as efficiently as it can be in steam, but it is found that a small quantity of steam formed from water allowed to drip into the heater is advantageous in assisting the heating of the air, and also in increasing the volume; but it is not clear that such an addition of steam to the air is desirable with a turbine, however beneficial it may be in a cylinder engine.

Air is about twice the density of steam, hence its velocity of efflux from a nozzle is about half that of steam. This at one bound reduces the turbine difficulties by one-half, by using air as the fluid instead of steam. Again, there is, or should be, no moisture in the air even when expanded to atmospheric pressure. This is another advantage.

The limits of P_a and T_a are determined only by the air pump, and the limits of T_1 by the construction and material of the air heater.

Theoretically, the air should be compressed adiabatically, but practically it is desirable to cool it in the pump to get a greater weight of air compressed.

A partial flow turbine is preferable for several reasons, principally because the wheel may be large in diameter and have large buckets, and also because leakage of fluid is reduced. At same time it gives a slower speed of revolutions. To reduce the speed of the buckets it is also necessary to resort to the compounding, that is, to have a series of wheels.

It is necessary here to distinguish between the different types of wheels. Now that the pioneer patents on fluid pressure turbines have expired, there is a movement among enterprising patentees to claim as new many things that are old.

First, then, a reference to Volume I. will show that "compounding" of turbines was known to the ancients, Pilbrow and Wilson; and Pilbrow shows a "compound" partial flow turbine, with large wheels and one nozzle, from which the steam expanded before entering the bucket. Compounding turbine wheels was patented by several others afterwards.

Following these pioneers came Parsons, with his complete flow turbines compounded like one of Wilson's, and then followed De Laval with his partial flow single wheel like one of Pilbrow's,—only, he expanded the steam in an expanding nozzle. Pilbrow knew of the expansion required, and let the steam expand naturally in the distance between the nozzle and the wheel bucket.

Then followed Ferranti, with a partial flow turbine with expanding nozzles and a number of wheels in series, one set of nozzles on several wheels in series. Curtis followed Ferranti by putting a number of Ferranti turbines in series, his turbine consisting of a number of turbines in series, each turbine consisting of a number of wheels in series with a set of expanding nozzles. The different steps may be shown in the evolution of the partial flow impulse turbine by a diagram of each.

Fig. 215 shows the Pilbrow multiple wheel, in which the nozzle was $\frac{3}{4}$ inch clear of the buckets, in order to allow the steam jet to expand and gain full velocity. Patented 1843.

Fig. 216 shows De Laval's single wheel and expansion nozzle. Patented 1889.

Fig. 217 shows Ferranti's multiple wheels and expansion nozzle. Patented 1895.

Fig. 218 shows Curtis multiple wheel and expansion nozzle turbines in series.

Fig. 219, patented (No. 269) 1903, is an improvement of some value for multiple wheels

and expanding nozzles. This invention relates more particularly to fluid-pressure turbines, in which the reacting elements rotate in opposite directions. The inventor suggests that in such turbines as at present constructed the forces applied to one wheel are greater than those applied to the other. In order to overcome this difficulty, and that the two rotating turbine wheels may be of like power, so as to be suitable for driving connected dynamos, the steam inlets are so disposed (as at *a*, *b*) that both wheels act in part as primary wheels and as secondary wheels. There might be a non-rotating centre wheel *c* between the two rotating wheels, as in Fig. 219.

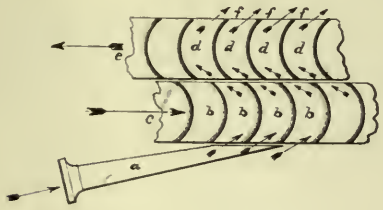


FIG. 215.—Pilbrow.

Fig. 220, patented in 1848 by Wilson as a multiple expansion compound turbine, which by the same process and like means performs all that Curtis claims, but on one wheel, the steam expanding through different parts of the same wheel.

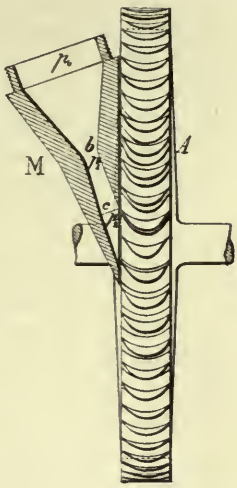


FIG. 216.—De Laval.

All these are shown in diagram, and they are all, with the exception of De Laval multiple expansion turbines, or as our American patent agents elegantly put it, with a "plurality" of wheels and guide nozzles.

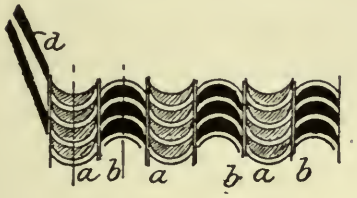


FIG. 217.—Ferranti.

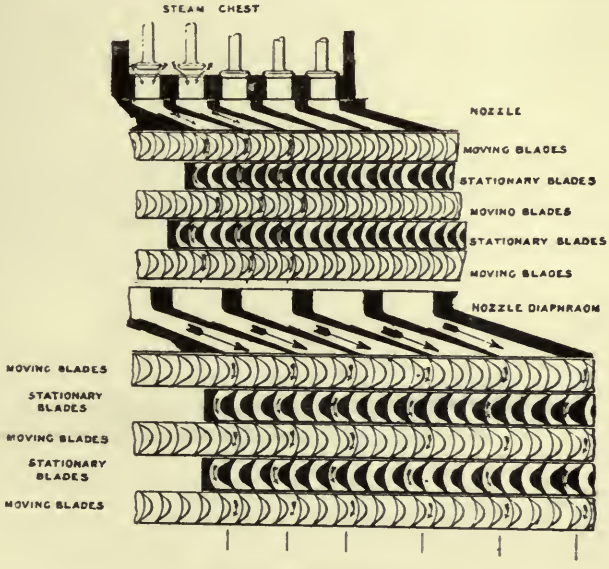


FIG. 218.—Curtis.

"Plurality" is perhaps patentable, but turbines with a plurality of turbines in series, and each with larger guide and wheel passages than the previous one in the series were not new twenty years ago.

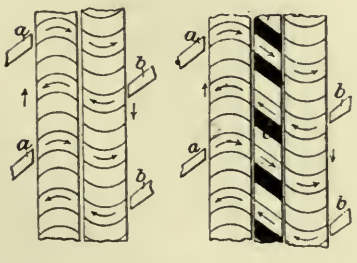


FIG. 219.

These, of course, are all steam turbines, in which the fluid velocity is very high, and

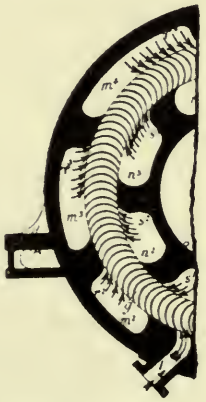


FIG. 220.—Wilson.

therefore multiple or a "plurality" of wheels are most necessary. With only one wheel, as has been long known, the speed of the buckets must be about half the speed of the fluid; with two wheels it may be reduced to one-fourth, and with three wheels, one-sixth of the speed of the fluid.

Air having twice the weight, delivers the same energy with same consumption of heat as steam, but at half the velocity, so that a turbine worked by air may have a slower bucket speed. These wheels are all suitable for air as the working fluid.

PETROL HYDRAULIC BOAT ENGINES

This boat, designed primarily as a fire extinguishing machine, has been built by Messrs. Merryweather & Sons. Having plenty of high pressure water at hand, naturally jet propellers have been applied. The combination as a whole seems admirably adopted

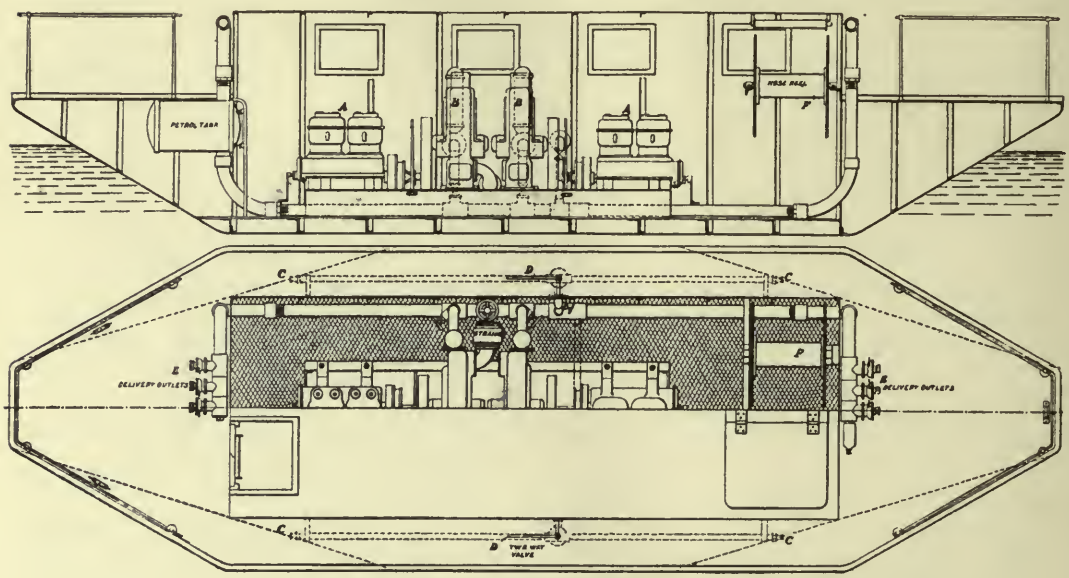


FIG. 221.—Plan and Elevation of Petrol Hydraulic Boat.

for river and harbour fire extinguishing purposes. Petrol is used in this case, but no doubt ordinary paraffin or kerosene can also be employed.

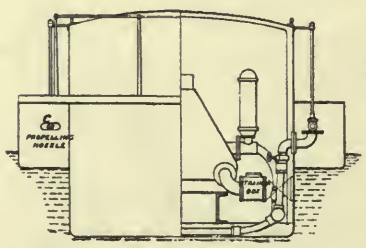


FIG. 222.—Cross Sectional End View.

It certainly shows the trend of progress in internal combustion engine applications, where steam hitherto has held the field alone. This boat is for use on the canal which passes through Messrs. Huntly & Palmer's works at Reading. Her hull is 32 feet in length, 9 feet 6 inches beam, and has a draught of 2 feet 6 inches. It will pass under a bridge which has a clear headway of only 4 feet 6 inches from the water level. The general arrangement of the machinery in the boat is shown by Fig. 221, being a longitudinal section through the boat, and a plan with half the roof of the cabin removed; and Fig. 222, a cross sectional end view. The machinery consists of two 30 horse-power 4-cylinder petrol motors, which are mounted on one bedplate, and are shown at A, Fig. 221. Each of these engines drives, by means of lever-expanding clutches and spur gearing, a Hatfield high-speed treble-barrel pump B. The suction

is taken from each side of the boat, and both the pumps deliver into the same main pipe, which pipe supplies four jets, two forward and two aft, which are used as a means of propulsion for the vessel. The nozzles for these jets are shown at C, Figs. 221 and 222.

This mode of propulsion is very convenient, because by it the boat can be very easily managed, and the source of power is ready at hand, without an auxiliary engine. By using one jet at each end on opposite sides of the boat the latter can be made to turn round on its centre. The jets are controlled by levers placed on the deck, as shown at D. From the main pipe branches are also taken, which communicate with the six rack valve outlets E for hose pipes, and a monitor is now being fitted by means of which one large stream of water can be delivered when desired.

The engines and pumps can be driven together or independently, and the pumps are fitted with large suction and delivery air vessels. The ignition to the motors is of the high-tension type, duplicate accumulators and coils being fitted. A large compartment is provided at one end of the boat for two reels F, each of which will hold about 500 feet of hose.

The petrol tanks contain enough oil for ten hours' supply, and float-feed carburetters are used. Exhaust boxes of large capacity are placed at each side of the boat, with the object of giving silent running.

During the test one $1\frac{1}{2}$ inch jet was thrown, and also several smaller streams simultaneously. The maximum delivery of the pumps, when both are employed, is 600 gallons per hour, at a pressure of about 100 lbs. per square inch. During the test the boat did its work in a satisfactory manner, and ought to prove a valuable safeguard against fire in such works.

The description is from *Engineering* of May 20, 1904. No reference is made to the propelling performances, but these are of a secondary nature in such a craft. It would be interesting to make experiments on this class of boat into the jet propellor problems. Some simple tests possible on this vessel would prove of great value.

HYDRAULIC PETROL BOAT

In this boat, designed by the author, the screw propellor, shaft, and gearing are substituted by a centrifugal pump and a special patent hydraulic propellor.

Reference was made in Volumes I. and II. to several hydraulic or jet propellors in connection with prime movers of general types and with producer gas engines. Experience has shown that the simple jet is not an efficient propellor; the water issues from it at different velocities at different parts of its cross section, and much loss occurs in friction and eddy currents. In order to improve this state of affairs, turbine blades in an orifice in the bottom or sides of the boat have been adopted with improved results. The design and construction and the laws of turbine blades are very well known,—hence these can be applied at once with certainty as to results.

As applied to a petrol boat it is shown in diagram. Fig. 223 shows the pump and turbine blade propellor partly in sectional side view, and Fig. 224 shows it partly in end view. Fig. 225 is a plan of the boat and pump and engine.

The propellor turbine blades are shown in two series—one series for propelling ahead and the other for propelling astern; a slide valve operated by a handle closes one set of blades and opens the other as desired. And by half closing both sets the boat may be stopped, and any speed ahead or astern can be obtained by adjusting the relative openings of the two series of blades.

Thus by a simple slide valve all the effects of a complicated mechanical clutch and wheel gearing can be obtained without any shock or strains silently and smoothly.

The intake for the pump is shown with a grating having movable blades, but a

fixed grating is good enough for small boats. In this boat, which is 20 feet by 6 feet

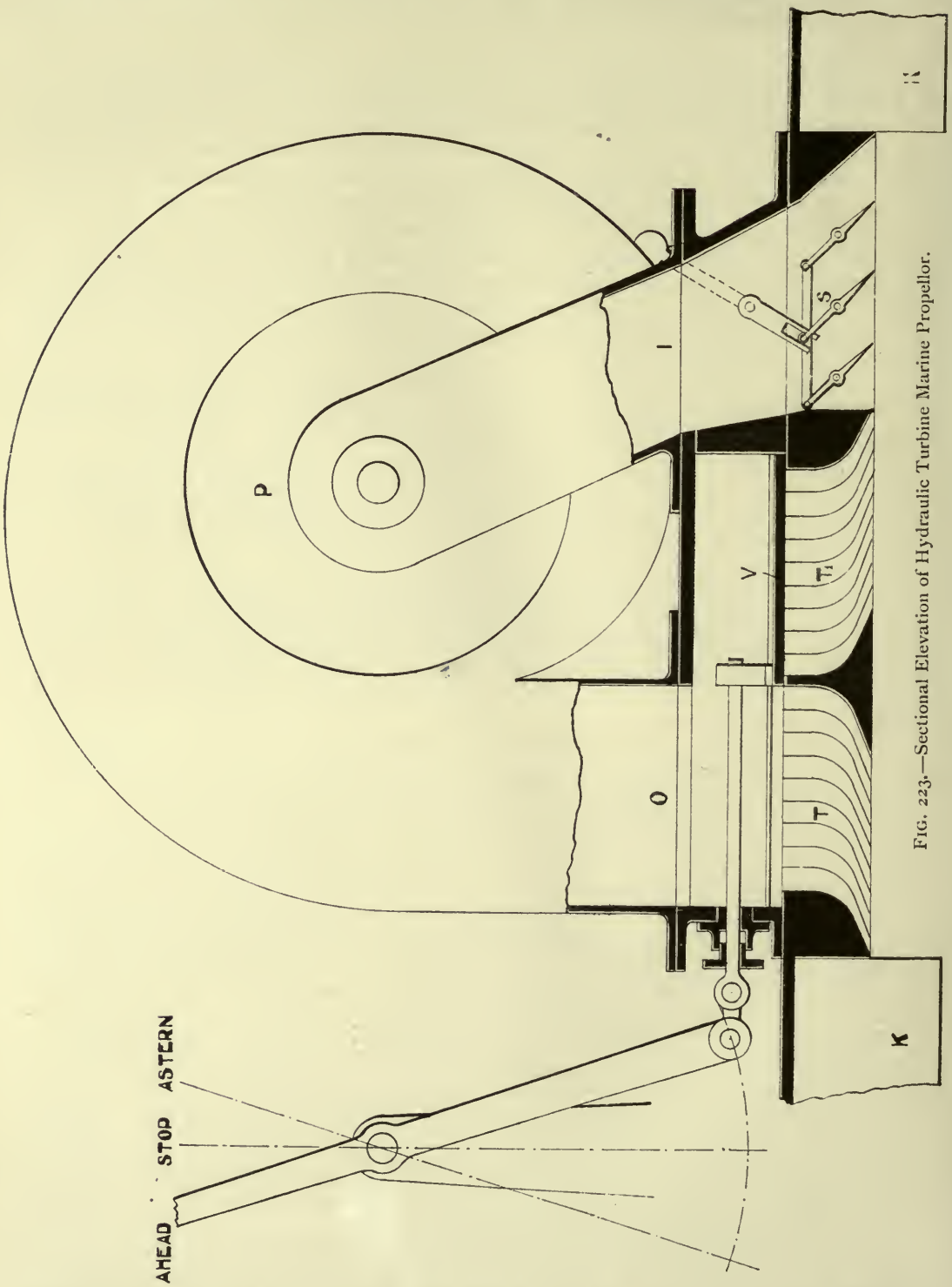


Fig. 223.—Sectional Elevation of Hydraulic Turbine Marine Propellor.

beam, the engine is 3½ brake horse-power tested, and the pump has a 4-inch delivery. It was built for convenience of experimenting, speed being of no account whatever;

we wanted to find "thrust" at different pump pressures, and different speeds of pump. A speed of about 8 knots could be obtained, quite sufficient for the verification of the scientific data. The best results, as was to be expected, were got when the slip and velocity of boat were equal; for the experiments the pump was belt driven, in order to be able to readily alter the relative speeds of engine and pump.

As an auxiliary propellor, this offers many advantages; there is no shaft and no external propellor. The whole plant, engine and pump and propellor, occupies little room

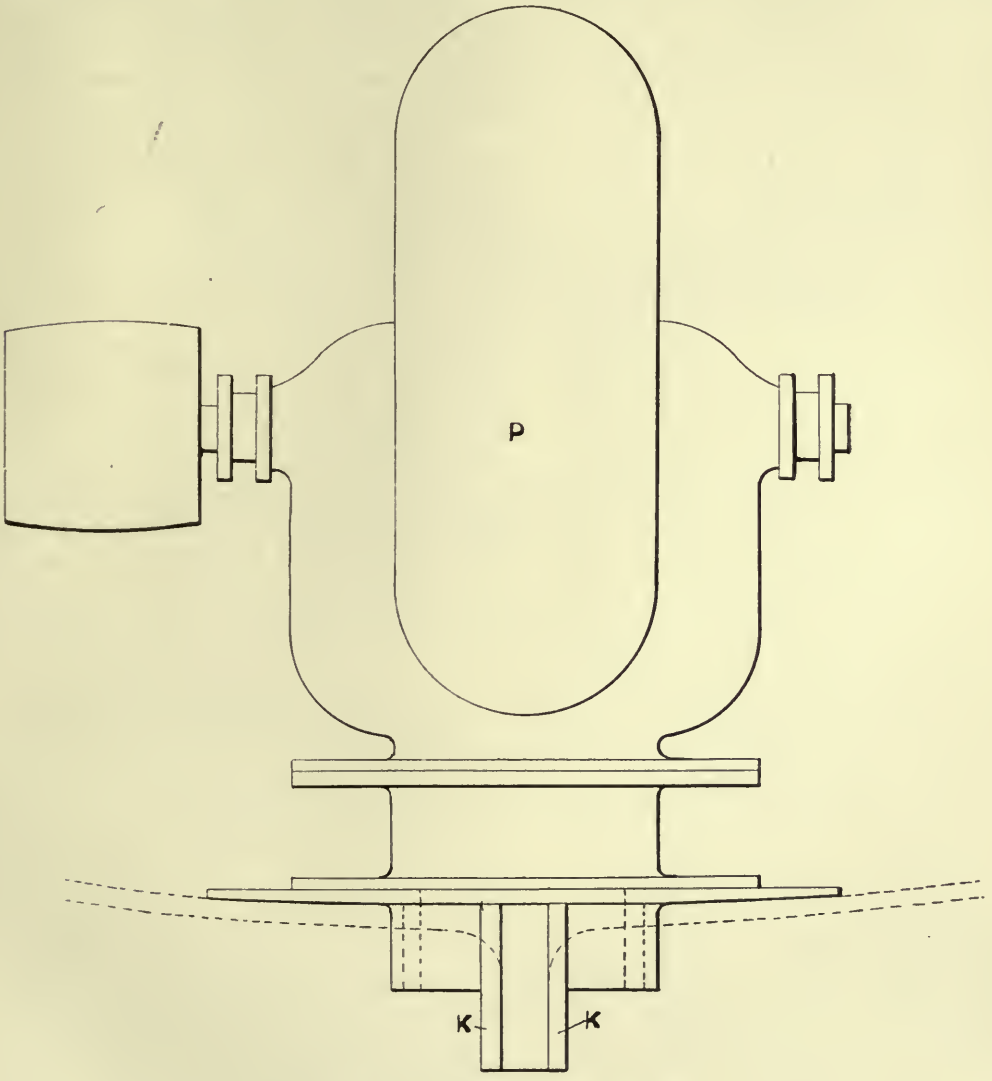


FIG. 224.—End View of Turbine Propellor.

and is entirely out of harm's way. For auxiliary propulsion on sailing yachts it has much in its favour, especially if the engine is made to run with the paraffin oil used on board as fuel for heating and lighting, and that is an easy matter.

Auxiliary powers need not be large, for the speed is generally sufficient if it reaches 5 knots in a calm;—the power required increases nearly as the square of the speed.

For yachts the engine need not be below the decks, it may be enclosed in a sheet-

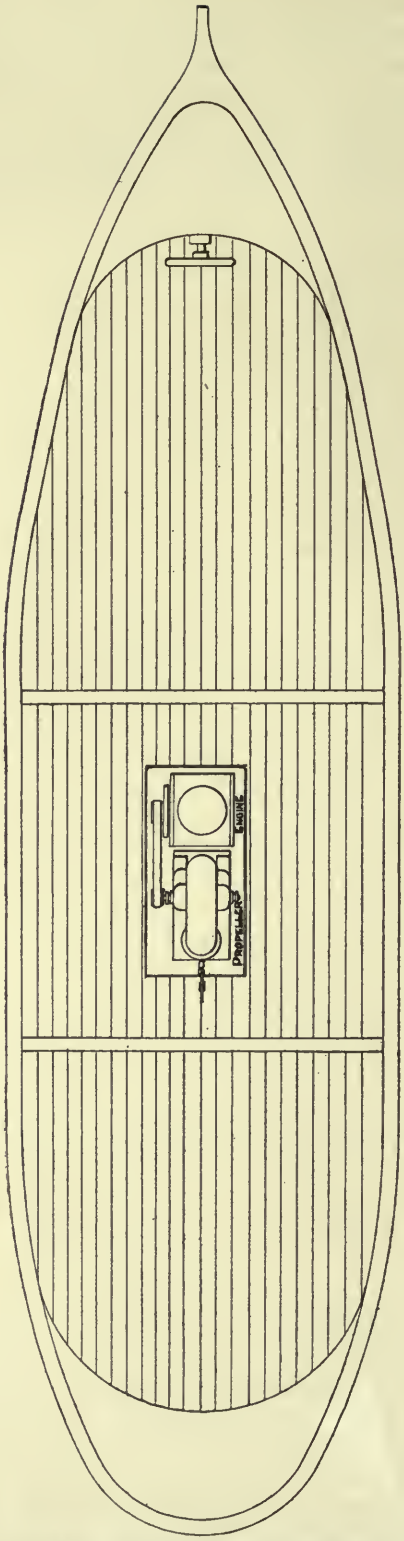


FIG. 225.—Plan of 21-Feet Launch fitted with Turbine Propellor.

metal engine room of small size on deck. With the pump attached the pump will lift the water, and the power expended in doing so will be returned when it falls again to the turbine blades. A hand-suction pump is used to pull up the water to fill the pump at the start.

The propellor shaft in the bottom of the boat, the outside propellor or screw, and the engine room in the bottom of the boat, are all objectionable features with a screw propellor as an auxiliary power for a sailing craft.

Again, for shallow draught vessels and high-speed torpedo and small naval craft the propellor inside the vessel has advantages which are obvious, especially if internal combustion marine engines are to be used, or even in the case of steam turbine marine engines. As these prime movers are no more reversible or easily controlled than internal combustion engines in regard to speed, high speed centrifugal pumps are more efficient than high-speed screw propellors.

The hope of all internal combustion engineering centres in the turbine, and when that has been realised the combination of the rotary pump and rotary turbine with the turbine blade propellor will be an ideal marine propulsion installation of modern machinery.

ENGINES OF STEAM MOTOR WAGGON

These engines are constructed by Messrs. C. & A. Musker, engineers, of Liverpool. They are interesting in having automatic regulation of the furnace air supply and other devices, which relieve the driver of anxious care about the water and firing of the boiler, so that he can attend without distraction to the driving and steering of the vehicle. This is attained, first, by a device which puts the pump out of action by raising the suction valve when the pressure of steam exceeds a certain determined limit; further, two dampers, one which supplies air to the furnace, and another which allows air to find access to the chimney, and so destroy the suction, are operated by the expansion of a part of the boiler. When the temperature of the boiler rises these two dampers are operated in opposite directions, the air to the furnace being cut off at the same time

that air is admitted to the chimney. The oiling of the engine demands no attention from the driver. There is a pump which delivers oil to all the bearings under considerable pressure, and keeps them constantly flooded. Another feature is that the whole of the engine and gearing is carried on a separate platform, beneath the platform which bears the load. Each platform has its own system of springs, so that whether the

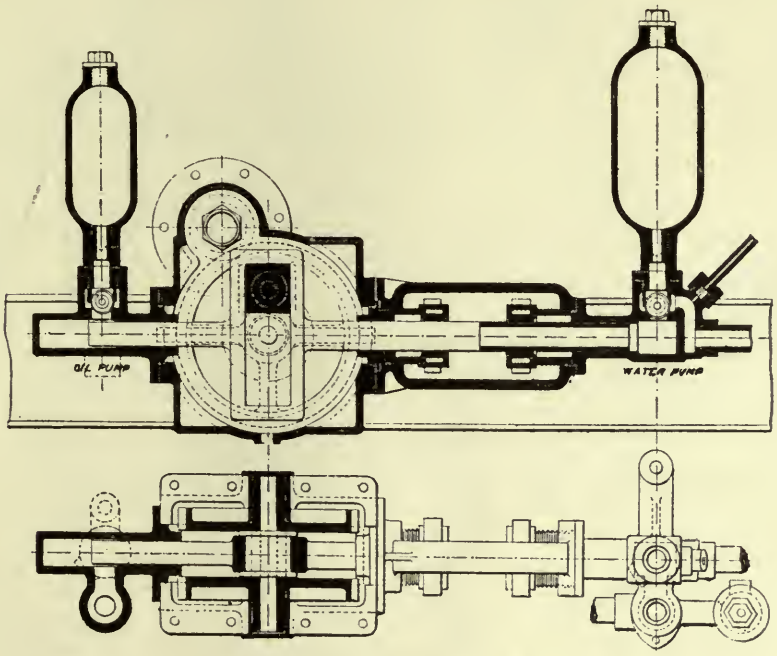


FIG. 226.—Water Pump and Oil Pump.

vehicle be loaded or unloaded, the position of the engine is not thereby affected. The furnace is of the type in which the coke is fed down by gravity from a hopper. This hopper is filled about every two hours, and the fuel gradually slides down on to the hearth—for there are no fire-bars—and is then consumed at the bottom. The driver therefore has only a minimum of attention to pay to his fire, which, as already explained, is stimulated by extra draught when the demands for steam are great, and is checked by the dampers when the load is light.

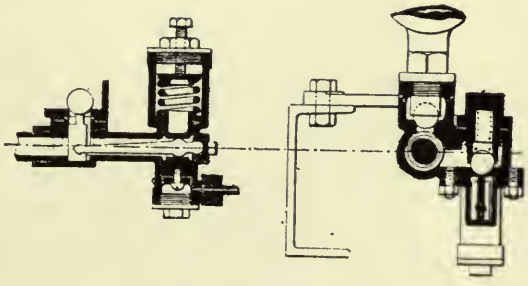


FIG. 227.—Suction Valve.

The boiler itself (Fig. 234) is of novel construction, of the semi-flash type, with a furnace having a solid bottom, and fed from above through a gas-tight hopper, through which the coke fuel is supplied at intervals of about two hours. The furnace is lined with fire-brick, which is renewed about four times a year; there are no fire-bars, so that the renewal of the brick lining about balances the renewals which would be required in an ordinary grate with bars.

The pump which supplies the water is shown in Figs. 226 and 227. It is worked by a pinion on the crank shaft. This pinion is long enough to gear with two spur-wheels (Fig. 226), which are connected together by a crank pin, which carries a block sliding in a slotted cross-head. Connected to the right side of the cross-head

is a plunger, with a gun-metal sleeve working in a pump barrel. The suction valve, which is a sphere, is shown in Fig. 227, and is mechanically lifted to stop the action of the pump when the steam pressure rises. The pressure governor is operated upon by the direct pressure of the steam, which enters by the small pipe (Fig. 227), and comprises a small piston and cylinder, with a lever passing through the piston. The longer end of this lever is fitted into the hollow cap screwed into the body of the governor, and the shorter end engages with the fitting which lifts the suction valve when the pressure on the inside of the piston overcomes the spring on the top of the piston. A cup leather is fitted to the inside of the piston, and the pressure is conveyed by a small copper pipe from the delivery of the pump pipe to the cylinder of the governor. The average working pressure is 275 lbs., and a safety valve is used to blow off at 450 lbs. If upon very long and steep hills the delivery of the pump should prove insufficient, it

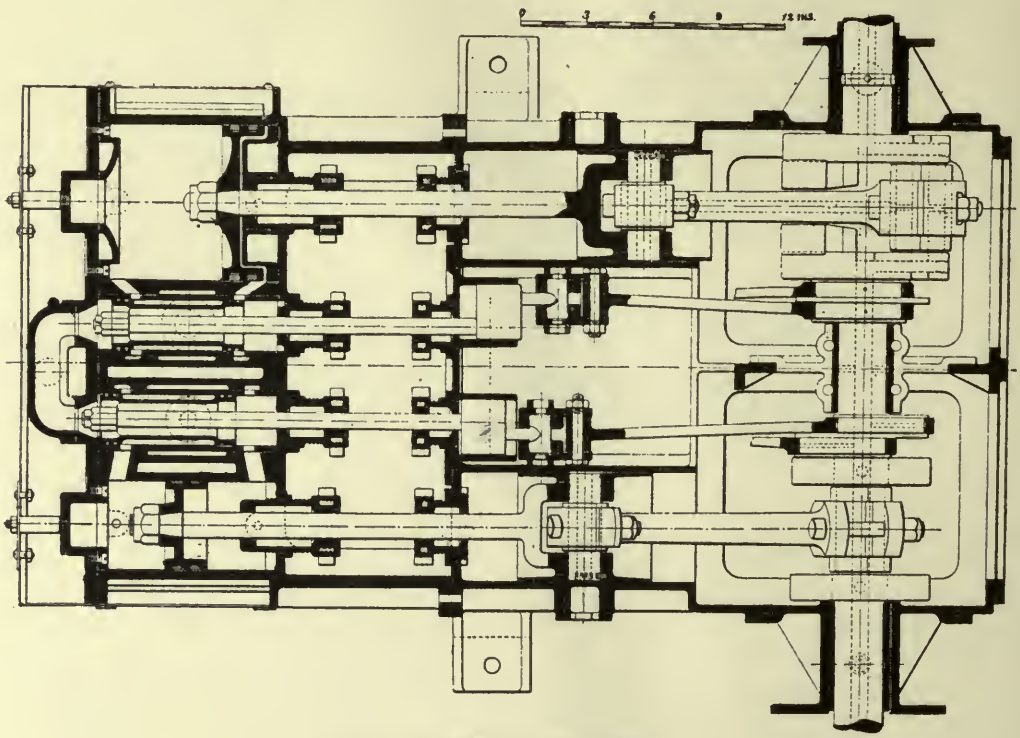
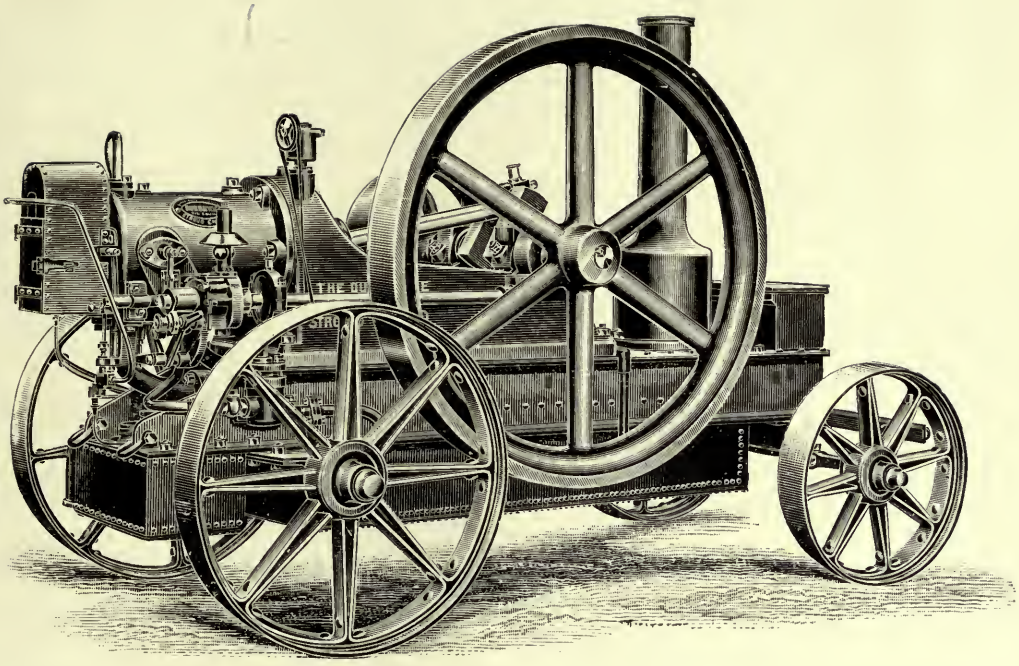


FIG. 228.—Musker Steam Motor.

can be supplemented by a small direct-acting steam pump, which is used for supplying water to the boiler when steam is being raised. The suction valve of the pump is lifted at 250 lbs. ; when the pressure falls to 200 lbs. the suction valve is lowered, and the pump again supplies water to the boiler.

The method of carrying the engine and gearing is clearly shown in Fig. 230. It will be seen that there is a platform or frame made of channel steel, supported at the front by plate springs, and suspended at the rear by spiral springs in such a manner that the shock of starting quickly, or of undue jolting, is absorbed by the springs, and is prevented from injuring the gear or the engine. The engine (Fig. 228) is compounded, the cylinders being 4 inches and 7 inches in diameter respectively, by 5-inch stroke, and at full speed it runs 450 revolutions per minute, developing 25 brake horse-power. The valve gear is the Stevenson link motion, with large wearing surfaces. The steam can be taken nearly the full stroke at starting and under heavy loads, while the link can be notched up to almost mid-position when running on a good road with a light load. The



Portable Oil Motor.

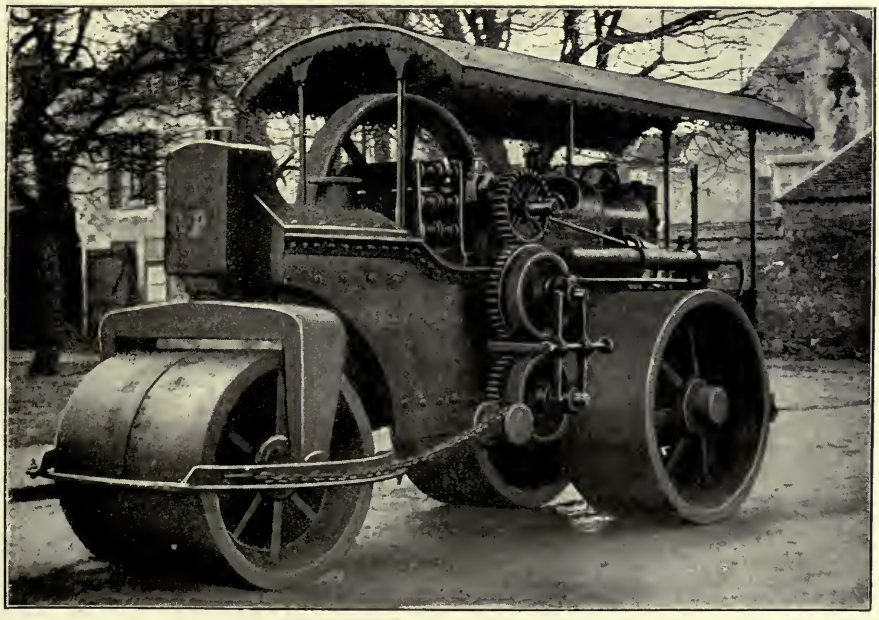


Plate VII.—Oil Engine Road Roller.

bypass from the steam pipe is fitted to the low-pressure cylinder, but is only used to warm that cylinder at starting. All the wearing parts are enclosed in dust-proof and oil-tight casing, to protect them from mud. The wearing surfaces are supplied with oil under a pressure of from 30 lbs. to 40 lbs. per square inch, and this pressure is shown on a gauge in front of the driver, so that he is always aware that the lubrication is being carried on properly. It is possible to trace on the drawings the passages by which the oil is led from one point to another, so that every bearing obtains an ample supply. The oil pump is shown in Fig. 226. It is mounted on the same slotted cross-head as the water pump. It will be seen that the plunger is not packed, and that the slight leakage which takes place enters the casing and keeps that filled with oil, so that there is continual splashing over all the working parts. In Fig. 229 it is shown how the oil reaches the valve motion. It is led by a pipe to a fixed case between the two links. Each valve guide has a pipe entering this case, and affording passage for

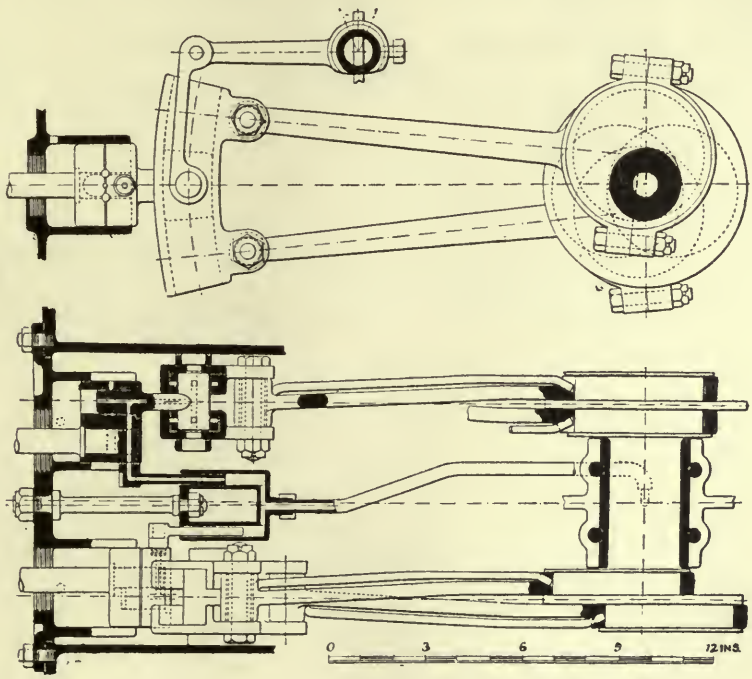


FIG. 229.—Valve Gear.

the oil first to the guide, then to the link, and finally to the eccentric. The crank shaft is bored with oil ways to the pins and the bearings, and there are also oil ways through the connecting rods to the cross-heads and slipper guides. It is stated that the bearings will run three or more months without any of the brasses being taken up. In addition, the steam which enters the cylinder is lubricated by a mechanical lubricator, driven by an eccentric on the second-motion shaft.

The driving of the wheels takes place through the usual differential gear, fitted with bevel wheels and pinions (Fig. 230); and there are two speeds of gear, the ratios from the engine to the driving wheels being 9.69; 1 and 18.2; 1 for the two gears. The second-motion shaft, which is made in two pieces, as is usual, has one piece bored up, and the end of the other let into it. The hollow shaft has a coiled spring inside it, against which the end of the solid shaft impinges. This spring puts a considerable degree of friction on the compensating motion to keep it steady. The power is transmitted to the driving wheels by steel pinions on the

second-motion shaft gearing, with toothed steel rings on the felloes of the road driving wheels (Fig. 231); by this means the power is applied direct to the wheel rim,

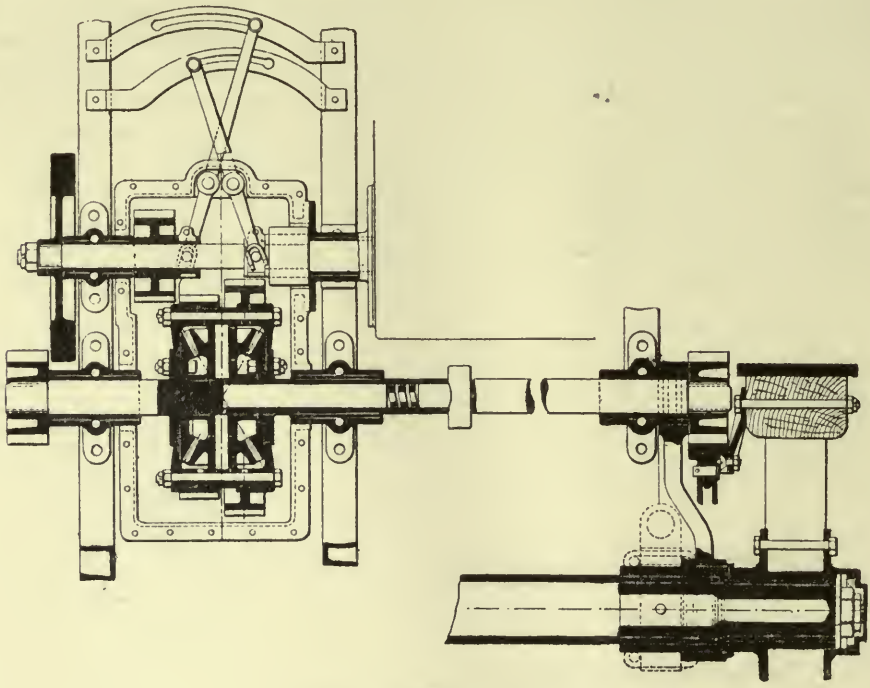


FIG. 230.—Driving Gear.

the spokes have only to support the weight. The leading wheels are 2 feet 9 inches and 6 broad, and the drivers 3 feet by 9 inches.

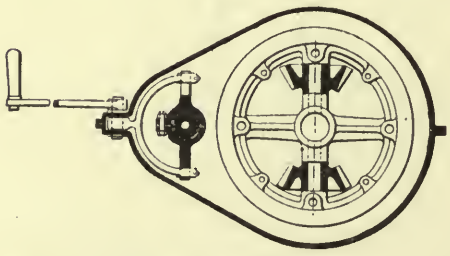


FIG. 231.—Driving Gear.

To raise steam at the start a hand lever is provided on the steam pump, whereby water can be pumped into the boiler under pressure up to 10 lbs. A fire is then made up, and in ten minutes sufficient steam is made to start the jet blowers. It takes about half an hour to start up from all cold. The water tank carries 160 gallons, sufficient for 25 to 30 miles journey; and 6 cwts. of coke, sufficient for 50 miles journey. The average consumpt of coke is 2 lbs. per ton-mile, and is as low as 1.6 lb. on good roads. The waggon will take 6 tons up a gradient of 1 in 8.

The arrangement of the boiler is shown in Figs. 233 and 234. It will be seen that this boiler is of the semi-flash type; that is to say, it has no fixed water level, the water flashing into steam as it rises up through the tubes, and being drawn off at the side. The water enters at the upper part of the boiler, and passes backwards and forwards through several rows of tubes. It then descends through an outside connection (Fig. 233, elevation) to the bottom of the boiler, where it enters a square section tube which supports the inclined plate (Fig. 234) forming the hearth on which the fuel lies, and down which it slides as it is consumed. After passing through this tube the water is led by a short connection (right-hand side of Fig. 233) to the boiler proper. The first nine tubes, counting from the bottom,

have walls $\frac{1}{2}$ inch thick, bent into sinuous form, and each joined at the end to a solid square steel column which forms the frame connecting these tubes together. The water enters at one end of the lower tube, and, passing through its entire length, reaches the other end, which is fixed in the second corner post. From this it passes up, through a hole drilled in the corner post, to another tube of the same form, this particular tube not being the second in the series, but the third, so that there is formed in the boiler two parallel sets of passages from the bottom to the top, through which the water flows in two parallel streams. The object of this arrangement is that should a tube be burnt through it can be plugged, and there will still be a circulating system left in which steam can be raised, until the waggon can reach a place where repairs

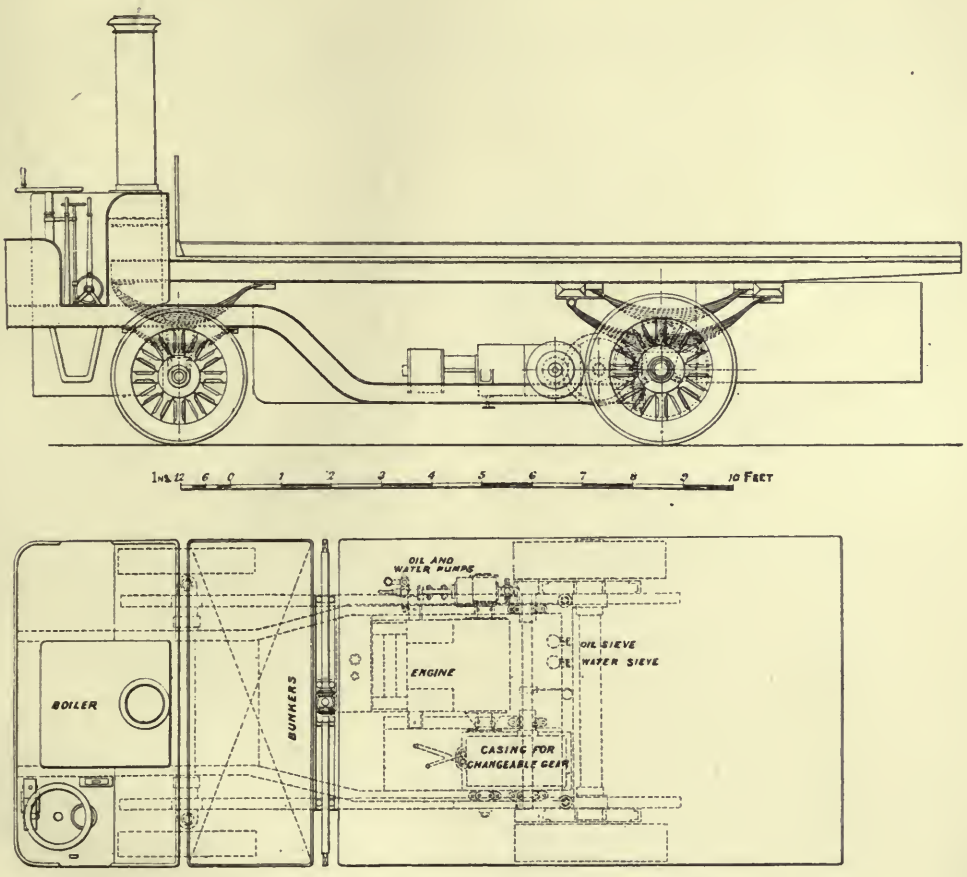


FIG. 232.—Plan and Elevation of Steam Waggon.

can be effected. The shape into which the tubes are bent is shown in Fig. 233 (plan), in which two tubes can be seen. The gases from the fire rise up through the spaces between the tubes, and have to pass twenty-one tubes before they reach the top and escape to the chimney. The tubes are free to expand as they like, and even the corner posts are only held by a slight sheet-iron framing. The lower sets of tubes are generally filled with water, and the upper set with steam, and water is continually pumped into the lower set under the control of an automatic regulator, as already referred to. When the steam pressure drops below normal, more water is pumped in; and when the pressure rises above the normal, the pump is put out of action. Usually the fire is only at medium red-heat, and when running light it is not beyond a dull red-heat. Owing to

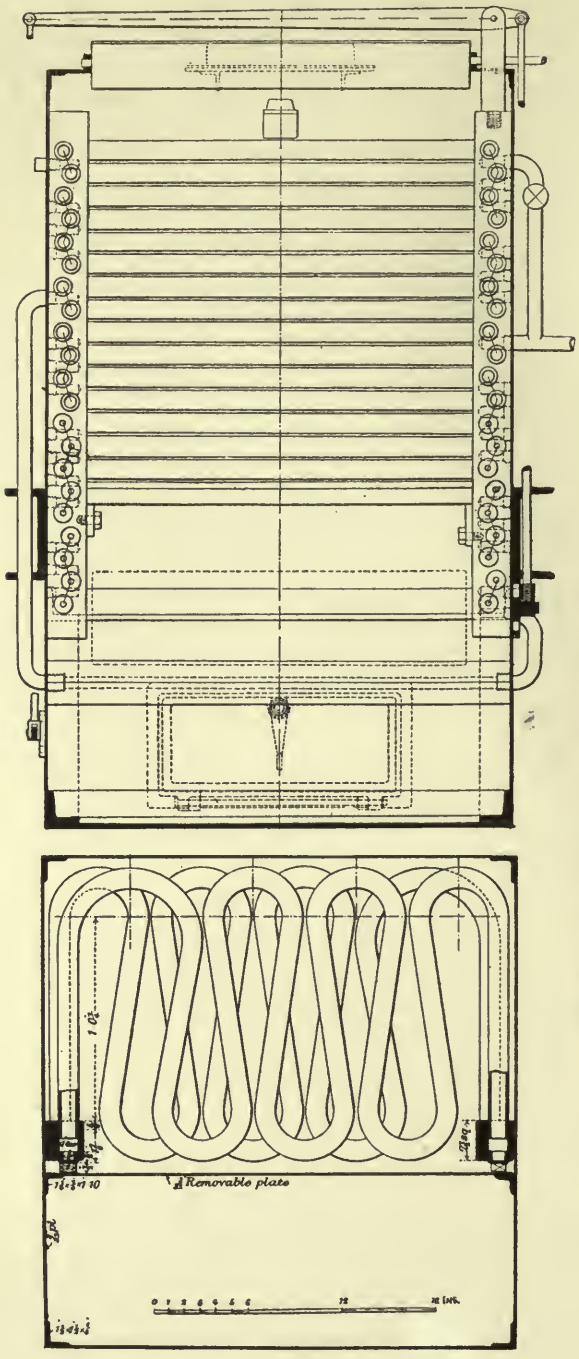


FIG. 233.—Plan and Elevation of Boiler for Steam Waggon.

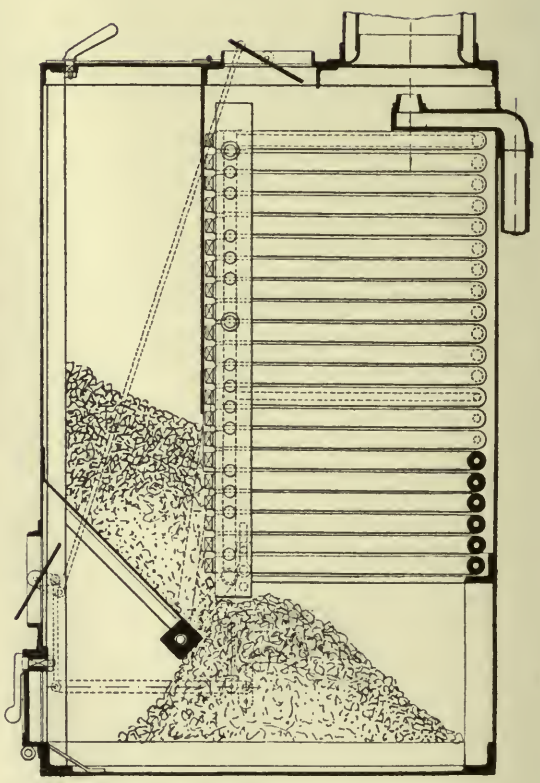


FIG. 234.—Cross Section of Steam Boiler.

the rapid and forced circulation there is, it is stated, no deposit on the inside of the tubes, and this contention is borne out by previous experience of boilers of the same kind. Further, the high temperature which the outsides of the thick tubes attain prevents any serious deposit of soot upon them.

One of the corner posts of the boiler has connected to it a multiplying lever (Fig. 234), which operates the two dampers, one of which, as shown, controls the air which passes into the furnace, while the other is at the base of the funnel. This lever is mounted on the top of the right-hand post (Fig. 233, elevation), and is tied down to the bottom of it by a tie-rod outside the furnace. When the post, which is about the temperature of the steam, expands, the left-hand end of the lever rises and operates the two dampers. These two dampers move concurrently in opposite directions, the one opening as the other shuts, and *vice versâ*. This arrangement causes the rate of combustion to correspond to the demands of the engine for steam.

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